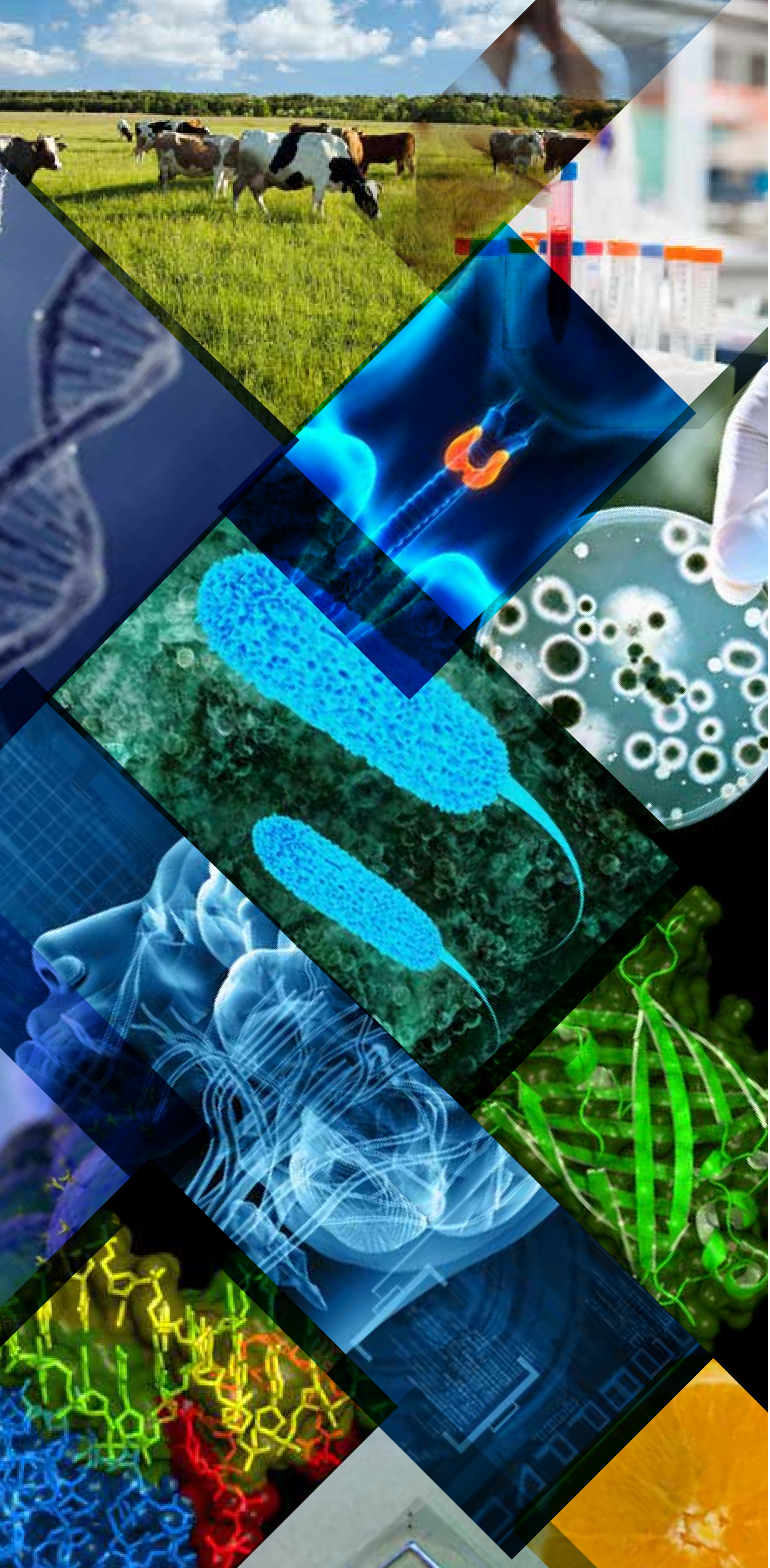
Royal Society of Biology

SPOTLIGHT ON THE LIFE SCIENCES

A GUIDE TO BIOLOGY CAREERS

A collection of articles and interviews on the many branches of biology from **The Biologist**



Contents

2 Foreword
4 Choosing a career

CORE BIOLOGY

6 Biochemistry
8 Ecology
10 Marine biology
12 Microbiology
14 Mycology
16 Physiology
18 Plant science
20 Zoology

MEDICINE

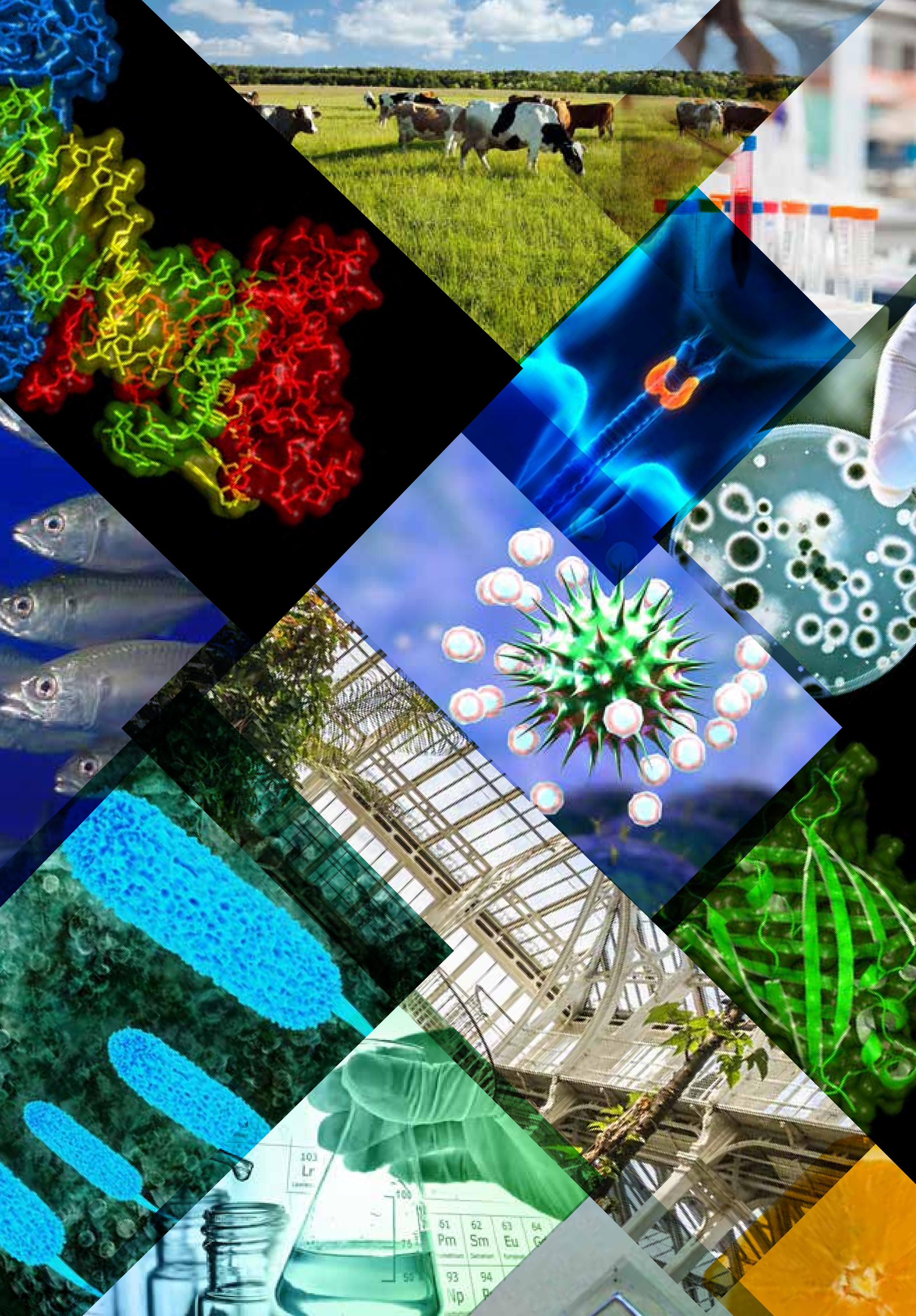
22 Bioengineering
24 Clinical trials
26 Endocrinology
28 Immunology
30 Neuroscience
32 Nutrition
34 Parasitology
36 Pharmacology

SPECIAL INTEREST

38 Aerobiology
40 Agroecology
42 Cryobiology
44 Photobiology
46 Sustainable agriculture

FUTURE BIOLOGY

48 Bioinformatics
50 Epigenetics
52 Proteomics
54 Synthetic biology
56 Systems biology


103
Lr
61 Pm
62 Sm
63 Eu

Foreword

The wonderful thing about biology is its immense breadth. Biologists study everything from the simplest life on Earth, like viruses or single-celled amoebas, to the human brain – the most complex object in the known universe – and everything in between. One biologist might study a billion tonnes of biomass in a distant rainforest, while another watches molecular interactions at a quantum scale.

But this diversity can also be bewildering. We all love science and nature, but the lectures that give some graduates a buzz can send others to sleep. Biology graduates can end up in an enormously diverse range of roles, from monitoring habitats on their local wetlands to drug discovery at some of the biggest companies in the world. Although the various disciplines of the sciences are increasingly encouraged to work together, the working lives of those in different areas of the biosciences can still seem worlds apart.

I think this is why the Spotlight On... series has been tremendously popular since it first appeared in *The Biologist* magazine in 2012. It's helpful sometimes to just get a feel for what these mysterious-sounding disciplines are all about and what careers they might lead to. It's useful to know whether you're going to be spending most of your time outdoors or in the lab, for example, or whether your work will be about making discoveries through research. Or solving practical problems. Or working with animals. Or people. Or numbers. We hope this collection of articles from the past two years will help you in this way.

Some of the sections of this booklet will be useful for people just about to choose an undergraduate degree, while the later ones might help graduates decide on the direction to take when considering a master's or PhD. Others may be looking to move into employment after their education, thinking of doing a higher level apprenticeship, or just considering a career break to study something that has always fascinated them.

This guide to the subdisciplines found in biology is by no means finished, as the boundaries between traditional subjects blur and increasingly merge with disciplines such as maths, physics and chemistry. New ones seem to emerge every couple of years, too. Do get in touch if you'd like any particular field to be represented in *The Biologist* in a future issue.

Tom Ireland, managing editor,
Royal Society of Biology

If you would like more in-depth information about career choices, or degree accreditation in the biosciences, please contact the Society of Biology's education team – details can be found at education@rsb.org.uk

Biochemistry

The study of the chemical processes that govern how living organisms work

Understanding the chemical properties of biomolecules is fundamental to modern biology

Biochemists investigate the structure, function and interaction of biological molecules such as proteins, DNA, RNA, carbohydrates and lipids.

Understanding the chemical properties of these large and complex molecules helps explain how living systems work.

Why is it important?

Some of the greatest breakthroughs in modern science have been in biological chemistry – for example, the discovery of the structure of DNA, and how it encodes instructions for development in all living organisms. Complex chemical processes are at the heart of all biological systems, from the replication of genetic information, to energy production, to the immune system – and therefore almost all branches of the life sciences depend on an understanding of biochemistry.

Synthesising biological molecules artificially is not only tremendously useful in medicine, but can also help us to understand how the very first life on Earth formed spontaneously from non-living material billions of years ago. Biochemistry is now very much an umbrella term for many more specific fields of biology, such as genomics, proteomics, metabolomics, synthetic biology and systems biology.

What careers are available?

Biochemists are employed in a huge variety of roles across the public sector, industry, and academic research. Biochemists are particularly important in healthcare, analysing samples for the health service and helping to develop treatments with pharmaceutical companies, research institutes and public health laboratories.

Other areas that biochemists work in include forensic science, agriculture, environment, biotechnology, food, energy and waste, or any organisation that requires chemical analysis of biological material.

Fundamental biochemistry research is also helping us find out more about the molecular basis of many diseases like cancer. Related fields such as synthetic biology and genetic engineering will allow us to create new strains of organisms that could help towards world issues such as food security and global warming.

How do I become a biochemist?

Biochemists working in academic research will normally have completed a biochemistry undergraduate degree (or something very similar – for example molecular biology, genetics or biology), followed by a further biochemistry related course of study up to PhD level.

Similarly, postgraduate qualifications are increasingly important for those entering industry or other sectors. Biochemistry graduates are also often employed in publishing and the sales and marketing of drugs and medical technology.

Where can I find out more?

The Biochemical Society is the largest discipline based bioscience society, with 7,000 members. It organises a variety of scientific meetings, resources, and awards and grants for its members, and publishes several journals.

● www.biochemistry.org

FIRST PERSON

Dr Greg Wallace

Profession
Head of biochemistry R&D, The Binding Site
Qualifications
BSc applied plant biology, Aberystwyth; PhD biochemistry/ plant pathology, Imperial; postdoc in biochemistry and microbial biotechnology, Nottingham
Interests
Immunoassays, polyclonal antibodies

What do you do?
I work for a company called The Binding Site, which deals mostly with antibodies. We develop assays that are ultimately used in hospital labs or the big commercial clinical labs in the US. We specialise in plasma proteins and those related to blood cell cancers. Our assays often don't give a a yes or no result, but give a value that hopefully agrees with clinicians' diagnoses or helps monitor a patient's response to treatment. Hospitals might run hundreds of these assays a day so they need to be fast and automated.

What does an average day involve?
I run the department, so an average day is a lot of meetings – about new projects and results, but also just the business of managing staff. My office is on a mezzanine floor overlooking the lab, and I still have a lab coat with my name on it – but not my own bench anymore. I like to come in early in the mornings and look over results from tests that have been running overnight.

Do you enjoy your job?
Yes, you have that overall job satisfaction when after two or three years of development a new product is being sold. But there is also the day to day satisfaction of being a scientist.

Like all scientists you get a buzz when you set up an experiment and results come through and it has worked. I've always liked lab work as opposed to in silica stuff and going through huge amounts of data. It's only recently I've 'gone upstairs' into a managerial role.

How did you get into this role?
My career path was fairly standard, I suppose. I started doing plant biology and my PhD was in plant pathology although really it was biochemistry - the source material just happened to be plant based. Once you are in the biochemistry industry and you have some basic technique knowledge, it is fairly easy to move around into different fields – few of the people in my team had any experience of working in clinical biochemistry before working here.

What areas of biochemistry do you think will be important in the future?
The miniaturisation of this sort of biology – nanobiology. Also personalised medicine being done in a way that is not horrendously expensive, for the masses.

Once you are in the industry it is fairly easy to move around into different fields

Ecology

The study of the interrelationships between organisms and their environments

Small changes to an ecosystem can trigger much larger environmental changes

Ecology covers a broad and diverse range of topics. However, it is generally agreed it is the study of the interrelationships between organisms and their environment, between different organisms and the structure and function of ecosystems.

Why is ecology important?

Ecosystems are at the heart of a range of important processes, such as the pollination of crops or the decomposition of waste.

On a larger scale ecosystems are key components of environmental systems such as the nutrient cycle and climate.

Small changes to any ecosystem can have a knock-on effect on many species and the environment. A better understanding of ecological systems will allow society to predict the consequences of human activity on the environment and protect ecosystems from damage in future.

How do I get into ecology?

Ecologists will need to have at the very least a degree in ecology, biology or a closely related discipline. Ecology is generally a field where master's and postgraduate level study is desirable, but not essential. Most successful ecologists have gained significant practical experience through independent study and voluntary work during their education.

What can I do with ecology?

Being such a broad subject area there are many professions that use ecology and many employers you can work for. These range from basic research in universities, research organisations (such as the Natural Environment Research Council) and museums, to working for non-governmental organisations such as the RSPB or the WWF. Ecologists can also find employment as conservationists, teachers and science writers, and even in government agencies that have responsibilities to promote or conserve the natural environment.

Where can I find out more?

The British Ecological Society can provide you with more information regarding ecology.

- www.britishecologicalsociety.org

The Institute of Ecology and Environmental Management (IEEM) is the professional body that represents and supports ecologists and environmental managers in the UK, Ireland and abroad.

- www.ieem.net

FIRST PERSON

Dr Lesley Batty

What does your job involve?
I am responsible for teaching, research and administration. I am the programme director for environmental science and environmental management. I teach several undergraduate and postgraduate courses, including biodiversity and conservation management, environmental transfer processes and remediation. I am responsible for securing research funding from organisations and ensuring that this research is carried out. This involves supervision of PhD students and postdocs.

What are your research interests?
Anthropogenic activities, in particular those associated with industry, generate a wide variety of waste products that find their way into the environment. As well as metals, oils and sewage, there are many new contaminants, including nanoparticles and medicinal compounds. My research centres around pollutants and their effects on ecological systems. I have done research on the effects of metals and nanoparticles on plants with a focus on aquatic species, and in particular the effect on physiology. Many organisms also show adaptation to pollution and can provide mechanisms that break down and transform pollutants within the environment. I am researching the potential for using plants to remediate land contaminated with multiple pollutants, focusing on the processes that occur around the plant roots.

How often do you work in the field?
As often as I can, although realistically I only have time in the summer. Most of my work is based in the UK, which makes it easier to 'pop' out for a day.

Did you become an ecologist by studying for an ecology degree?
No, I studied environmental science at university. About a third of the course was based in the animal and plant sciences department, which is where I learned most about ecology. However, it was David Attenborough who inspired me when I was young to take an interest in ecology.

Would you recommend it as a career?
Wholeheartedly. It gives you a very different view of the world and one that is much more rounded than many other subjects. It also provides so many different skills and opportunities that can be used in many jobs. My field is at the very applied end of ecology and so the more industrial partners you can get on board, the more likely you are to secure funding and get access to interesting field sites.

What are the hot topics in ecology and where do you see its future?
Climate change, and in particular the movement of species and changes to communities. There has also been an increased focus on marine ecology.

I see ecology becoming more integrated into other areas such as biosciences in general, engineering and environmental management. The challenge will be to ensure it remains a distinct discipline with all its associated scientific rigour.

Your research is funded by a range of bodies and you collaborate with lots of different departments. Is this aspect of your research a help or a hindrance?
In terms of funding it is a hindrance as it is more difficult to get the relevant expert reviewers who can see the bigger picture. But in personal terms it keeps me on my toes as I am always learning new things.

Pollutants at sea affect marine species

Profession
Lecturer in environmental science, University of Birmingham
Qualifications
PhD, MRes earth and atmospheric sciences, BSc (Hons) natural environmental science, Postgraduate Certificate in Learning and Teaching
Interests
Impact of pollutants on ecosystems and organisms, ecologically based soil and water remediation, wetland ecology

I am researching the potential for using plants to remediate land contaminated with multiple pollutants

Marine biology

The study of life in the sea and other saltwater environments

Fish, such as mackerel, are a crucial part of many people's diet

Marine biology is the branch of marine science that deals with all aspects of life in the sea, as well as other saltwater environments such as estuaries and wetlands.

Why is it important?

The oceans cover approximately 71% of the Earth's surface and the organisms within them are vital for feeding humans and giving us a stable climate. Marine phytoplankton produces about half of the oxygen we breathe and, globally, fish provides more than 1.5 billion people with almost 20% of their animal protein. There is increasing concern about the health of the oceans, which we know relatively little about.

Is it all working with dolphins?

Despite having a glamorous image, very few marine biologists actually work with dolphins, whales or with coral reefs. The majority work in applied areas related to fisheries or pollution, or concentrate on a specific group of marine organisms, such as viruses and plankton. Others look more broadly at marine ecology and how different groups of organisms interact. Marine scientists work in a range of settings, from universities and colleges, research councils, government agencies, private companies and non-profit laboratories, to local governments and international organisations.

What's the best route into a career as a marine biologist?

Students who are interested in pursuing a career in marine biology should opt for a specialist undergraduate course.

Universities which take a special interest in teaching marine biology are Aberdeen, Heriot-Watt, Hull, Liverpool, Newcastle, Bangor, Plymouth, Portsmouth, Swansea, St Andrews, Stirling, Queen Mary & Westfield, London and Southampton.

Students wishing to go directly into research following their first degree should be looking at PhD studentships in universities with strong marine science departments. Postgraduates who are looking to specialise in marine biology can consider a range of MSc or MRes courses.

The supply of marine scientists generally exceeds demand, but some specialist areas are in greater demand than others. Two areas where there is growing demand for specialists include molecular biology and biotechnology. Mathematical modelling within marine biology is also increasingly important, as more sophisticated mathematical models are required for effective management of marine resources.

Where can I find out more?

The Marine Biological Association is a professional body for marine scientists with some 1,200 members worldwide.

● www.mba.ac.uk

FIRST PERSON

Maya Plass

What are you working on at the moment?
An average day involves rocking up at the beach to take groups out with my education business Learn to Sea. We take them to different points along the Devon shore and the river Avon, teaching them about the wildlife and the different features, including some freshwater as well as marine environments. I've also done some TV work for BBC Coast and some guest presenting for *Autumnwatch*. I have a few branches of work but they all involve marine education as a theme.

Why do you think teaching people about marine biology is so important?
It's crucial to have a basic understanding of the sea and its importance to us, but there is no formal education in schools. Why don't most people know that atmospheric oxygen comes mostly from plankton, for example?

What are the most exciting areas of research in marine biology?
Perhaps more important than exciting, the MarCLIM project is all about trying to track and understand what is happening to coastal areas as a result of climate change. Half of all CO_2 emissions from fossil fuels are absorbed by the sea and it becomes more acidic. The implications for marine invertebrates are huge – the calcium carbonate exoskeletons of many species become weakened and research suggests organisms' dimensions are changing as a result. It's important for our commercial species, like lobsters, as well as from a more general biodiversity point of view.

How did you get into marine biology?
My interest started playing in rivers as a kid and the odd trip to the beach in Kent, which I loved. Then we would go on trips to Hilbre Island when I lived on the Wirral, and I was just enchanted by this alien world of rock pools and seals which no one seemed to know anything about.

When I said I wanted to study marine biology, my careers' adviser at school said I was living in a dream world and said I should be in people management – I think he thought I just wanted to swim with dolphins or something.

How did you then branch out into TV work and writing?
The TV and publishing work came really by accident. I had a volunteer working with us who had worked for *Springwatch*. She put me in touch and I did a rock-pool piece for them and ended up being a guest presenter. Then I was tweeting about rude Latin names on Twitter with someone who turned out to be a senior commissioning editor of Nature Books and things went from there.

Marine biology is seen as one of the more popular branches of the biosciences with lots of opportunity for travel. Is it like that?
There is some idea that we're all out sunning ourselves somewhere exotic, but most of my work is in the UK. I have worked in Hawaii and Argentina but even then, I was working hard. Yes, it may be a bit more glamorous than other branches of the biosciences, but you still have to work hard.

You need a huge passion for the subject. It is difficult to get into employment and you have to be prepared to do some volunteering first. You have to remain optimistic too, in the face of a pretty bleak outlook for our coastal areas. But there are lots of opportunities out there – you can work in a lab, at sea, or in policy, education and the media.

Life on the ocean waves isn't always exotic

Profession
Marine biologist, founder of marine education business Learn to Sea, author and presenter, patron of conservation group Sea-Changers
Qualifications
BSc marine biology and coastal ecology, MSc integrated coastal zone management
Interests
Marine education and conservation

When I said I wanted to study marine biology, my careers' adviser at school said I was living in a dream world

Microbiology

The study of microorganisms (or microbes)

Microbiologists think there are millions or perhaps even billions of different species of microbe on Earth

Microbiology is the study of microorganisms (or microbes). They are are found in every habitat on Earth, including in and on humans, and make up the vast majority of the diversity of life on Earth. Scientists estimate that there are 2-3 billion species and they occur in an amazing variety of shapes and sizes. Microbes are divided into one of six groups: fungi, bacteria, algae, protozoa, viruses and archaea.

Microbiologists study microbes both in the lab and in their natural environment; examining their survival strategies, how they interact and how we can exploit their activities. Microbes have a huge impact on our lives – in both positive and negative ways.

Why is microbiology important?
Microbes play key roles in health, food production and the environment. They can cause disease, but are also used to make antibiotics that fight infections and vaccines that prevent disease. Microbes also play key roles in climate change – they are responsible for most of the methane produced on Earth, but also produce over half the oxygen and are used in the production of biofuels. Microbes are responsible for cycling carbon and nitrogen, helping plants acquire nutrients from soil, and they can even be used to help clean up pollution.

How do I pursue a career in microbiology?
Most microbiologists have a university level qualification in either microbiology or more general biosciences. A full list of first-degree microbiology courses is available on the Society for General Microbiology (SGM) careers website. Universities, research institutes, hospitals and industrial companies employ microbiologists to do medical, environmental, healthcare and agricultural research. Microbiologists are also employed in hospitals to diagnose and monitor disease. Industrial microbiologists work in a range of companies, from big pharmaceutical, biochemical, biotechnology and food businesses to smaller companies developing specialist microbial products.

Where can I find out more?
The SGM provides information on diverse areas of microbiology through podcasts, briefing papers, educational resources and an in-house magazine, *Microbiology Today*. As well as a careers site, SGM also has an education website which contains information and activities to support microbiology teaching and learning in schools.

● www.microbiologyonline.org.uk

FIRST PERSON

Dr Karen Robinson MSB

Describe a typical day.
I lecture medical students and postgrads on infections, immunity and cancer. I manage a research team, supervise PhD students and postdoctoral researchers, and do some experimental lab work.

What are the hot topics in microbiology?
One is synthetic biology, which has the potential to allow us to build microbes artificially. From a medical perspective, there's a lot going on to find out about the myriad of harmless bacteria that are present in our bodies. Many of these organisms cannot be cultured, but we're realising that they have a big impact on health.

What's the focus of your research?
We're studying how infections in the gastrointestinal tract cause or even prevent disease in people that they infect. We're especially interested in a bacterium called *Helicobacter pylori*, which is the main cause of stomach and duodenal ulcers and stomach cancer. Most people don't ever have any problems from this common infection, but in those who develop stomach cancer only about 15% survive five years. I'm also interested in the 'hygiene hypothesis' – how we need exposure to certain infections as children to prevent conditions like allergy and autoimmunity.

Does there appear to be a clear link between sterile conditions as a child and the development of autoimmune disorders and allergies?
People are finding associations, but it's quite difficult to prove. There are animal studies showing directly that infections can protect against allergies and autoimmune diseases, but there are so many factors to take into account. Genetic susceptibility to these conditions plays a big part too, so you probably need susceptibility in your genes in the first place. Perhaps if you have the right infections and the right kind of environmental triggers, this can protect you. But if you don't have that protection and are genetically susceptible, you'll be more likely to develop the condition.

Craig Venter famously built an artificial genome and successfully implanted it in a 'hollowed out' existing bacterial cell. How close are we to being able to genuinely build a bacterium from scratch, and what would the implications be?
I'm sure people are working towards it, but I think that's still a way off in the future. The implications are huge. We use microbes to do all sorts of things in our daily lives – to be able to just build something to do what you want is going to be so powerful.

Where is microbiology headed?
Microbiologists are working more and more with scientists from other disciplines to find solutions to global challenges like food security. Technological advances are also making a big impact – it's possible to have a bacterial genome sequence in days, rather than years. This is transforming microbiology, providing us with so much information that we didn't have access to before. I expect it'll become a standard lab technique, leading to many breakthroughs and products. As the process gets faster and cheaper, it will probably become a standard diagnostic test, which is mind-boggling.

What roles can bacteria play to mitigate the effects of global warming?
Biofuel research is really taking off – scientists are engineering bugs so that they can produce chemicals that are more efficient biofuels. As a strange example, kangaroos apparently don't produce much methane, so people are trying to figure out what bacteria they have in their gut and whether you could manipulate farm animals to have the same kinds in theirs.

Do you have any advice for budding microbiologists?
Microbiology is a fundamental part of so many disciplines and technologies, so there are lots of diverse career paths.

Profession
Professor of infections and immunity, Nottingham
Qualifications
BSc (Hons) in bacteriology and virology; PhD in immunity to infection; both from The University of Manchester
Research interests
Interactions between gastro-intestinal infections and host, especially *Helicobacter pylori* infections of the human stomach

We use microbes to do all sorts of things in our daily lives

Mycology

The study of fungi

Fungi are the primary decomposers of organic material in many ecosystems

Mycology is the study of fungi. It is closely associated with plant pathology as fungi cause the majority of plant disease.

Why is mycology important?
Fungi are the primary decomposers of organic material in many ecosystems and so play a crucial part in recycling nutrients and the global carbon cycle. They break down pollutants and the most durable organic materials and have a range of uses such as in medicine and food production. At least 80% of plants rely on mycorrhizal associations – symbiotic relationships between the plant's roots and a fungus that provides the plant with water and nutrients.

What careers are available?
Purely fungal science roles are quite scarce, but at the same time there is a severe shortage of mycologists, plant pathologists and taxonomists, and these disciplines are taught less and less in universities. Still, mycologists can find work in many areas. The importance of fungi in crop growth, plant disease, fermentation and spoilage means there are jobs available in agriculture and the food industry. The unique properties of fungi offer many other industrial applications, such as the bioremediation of polluted land, while medicinal mycology researches potential pharmaceutical uses.

How do I start?
There are no undergraduate courses in mycology in the UK so most mycologists embark on postgraduate research after doing a more general bioscience or microbiology degree. Where mycology is taught as part of a bioscience degree, hospital-based universities tend to concentrate on pathogenic fungi, while others may focus on fungal ecology and plant pathology. Due to a lack of formal training opportunities, academics and employers look for an interest in fungi and a background in plant sciences or microbiology.

Where can I find out more?
The British Mycological Society is a charitable organisation for those working, studying or interested in mycology. There is a strong amateur contribution to the recording, discovery and conservation of fungal species in the UK, with many groups (including the Society's local branches) organising 'fungal forays' into woodland to find interesting or edible specimens.

- www.britmycolsoc.org.uk
- www.societyofbiology.org/branches

Kew Gardens' fungarium holds 1.25 million specimens and visitors can also see an excellent variety of fungi in its arboretum.

- www.kew.org/plants-fungi/fungi

Information on events in the London area can be found at Fungi To Be With.

- www.fungitobewith.org

FIRST PERSON

Professor Lynne Boddy FSB

What led you to study fungus?
My first encounter with fungi was in student accommodation – I tried to open a cupboard drawer and found it was stuck shut. I prised it open and there was masses of mycelium attaching the drawers together. Then I tried to pull the whole thing out and found it was stuck fast to the wall. It was the dry rot fungus *Serpula lacrimans* – its chords can penetrate brick and plaster. It was then I thought, "hey, these are cool".

I studied biology at Exeter University where the famous mycologist John Webster worked. For my PhD I started looking at the process of wood decay, but I instantly realised we needed to know more about the fungi involved.

Describe a typical day.
I spend my days teaching and doing research. I do lots of outreach work to get people to understand why fungi are important and why they are fun to study. Doing hands-on things in the lab is a rare treat – my postgrads do most of it – but when they go out on field work I always try to accompany them. About 85% of our fungal ecology experiments are done in the lab.

What are you working on now?
I study wood-decaying fungi and fungal communities – they're much like communities of plants except they're harder to study as they're hidden. My work is about what all these species are and what affects how they interact.

Fungal species fight with each other all the time and I liken these interactions to the football Premier League. You have your Manchester United fungi, who win most of the time, but sometimes a less successful team beats them. Why? Environmental changes or the presence of invertebrates or bacteria alter these interactions.

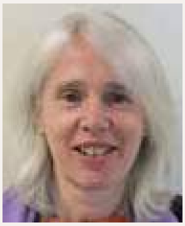
I also work with cord-forming fungi. They don't just release spores and hope they land somewhere suitable, they grow mycelium out of the wood and create long foraging structures that search the forest for more dead wood to colonise. Like mycological motorways, these huge structures can shift nutrients around a forest in a matter of minutes, and actually behave a little like animals – when you compare their growth patterns to foraging patterns of ants or termites they're very similar.

What are the potential applications of your work?
Because they are such good fighters, fungi could be used as bio-control agents to prevent the spread of disease. Plus, they are amazing recyclers. I want to find out how we can manipulate them to help nutrient cycling, waste disposal and bioremediation.

Why are there so few mycologists?
There are only a handful of taxonomists left in institutions, which, when you have 1.5 million species of fungi and only 100,000 have been described, is disastrous. We have a couple of flourishing mycology research groups, but the number elsewhere is dwindling. People retire and don't get replaced. There are more and more biology degrees where fungal biology is not compulsory and some where you don't get taught any at all, which is worrying considering how important fungi are.

There are two groups of people in mycology: those who specialised in it after doing a biology degree, but also many skilled amateurs and enthusiasts. We are indebted to them and their discoveries, and taxonomy is often in their hands.

Aspergillus under an electron micrograph

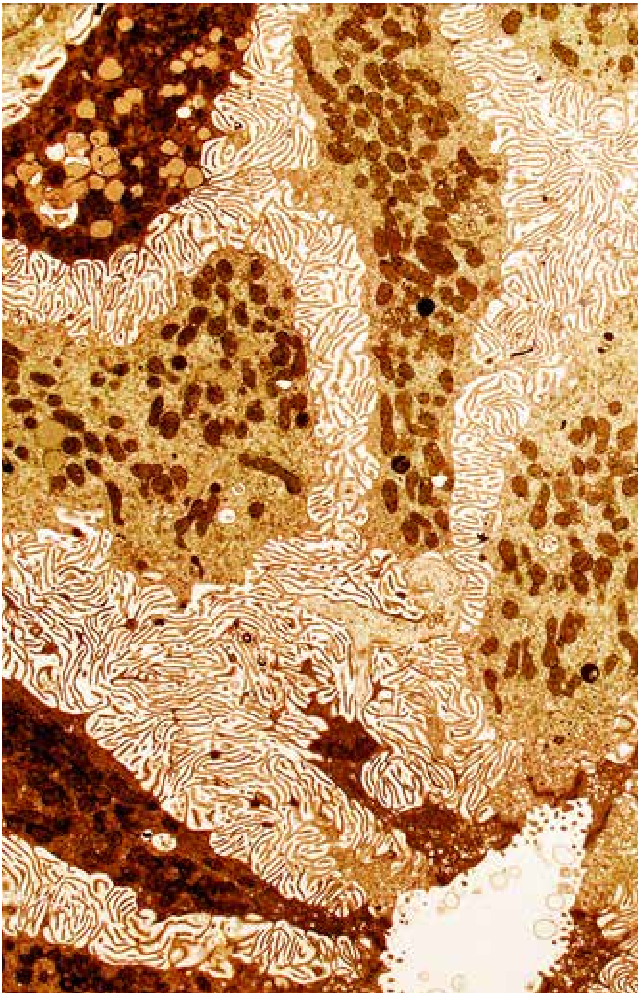


Profession
Professor of mycology at Cardiff University
Qualifications
BSc in biology and mathematical statistics from Exeter; PhD in botany (wood decay) from Queen Mary, London; DSc in ecology of wood decomposition from Exeter
Interests
Fungal communities in wood; ecology of cord-forming basidiomycete fungi; climate change effects on fungi; role of fungi in ecosystems; ecology of rare and endangered fungi

Fungal species are great fighters

Physiology

The science of how organs and whole organisms work



The salt gland of a crocodile seen under a microsope

Often described as the science of life, physiology is the science of how the body works. Cellular and molecular biology have enabled us to strip the body down to its constituent parts, but physiology is about putting those components back together and understanding how they interact. Physiologists study every aspect of how organisms function, from the actions of individual proteins within cells to how organ systems interact in the body.

Why is it important?

Physiology provides a foundation for all of the biological and clinical sciences. Physiologists in the lab use their understanding of how the body functions to try to find cures for diseases, such as cystic fibrosis and Alzheimer's. Neurophysiologists work on brain function, understanding how we learn and remember, and why it sometimes goes wrong. Clinical physiologists work in hospitals and clinics, diagnosing and managing disease.

However, not all physiologists work in a lab. Exercise physiologists, for example, apply their science to help athletes reach the peak of their performance, while others apply their knowledge more broadly to assess how exercise can help the general population combat ageing and cardiovascular disease.

What's the best route into a career in physiology?

If you have studied biology at any level, you will have studied physiology. Most physiologists will have studied a biomedical science or sports science degree at university level. Following university, many will take a postgraduate qualification in the area of physiology that most interests them.

However, not everyone will continue to postgraduate level. Many people choose to go straight into industry or clinical roles, gaining experience alongside professional qualifications. Some go on to study medicine or dentistry, but due to the breadth of the subject, physiologists really can be found in all walks of life.

Where can I find out more?

The Physiological Society offers information about diverse areas of physiology. Here you can find information on public engagement activities, meetings and training courses. You can also find back issues of the Society's magazine, *Physiology News.*

● www.physoc.org

A range of similar international Societies exist, such as the American Physiological Society.

● www.the-aps.org

FIRST PERSON

Professor Samuele Marcora

What are you currently working on?
My main speciality is the role of neurophysiology and psychobiology in people's perception of effort and how it is nearly always athletes' perception of fatigue, not muscle or cardiovascular fatigue, which limits performance.

Also, how mental fatigue limits performance. Every time a football manager's team performs badly you'll often hear them say they were mentally tired or under pressure, but there's very little science on it, while there is an awful lot of research about muscle fatigue.

There are two main theories on how you perceive fatigue: the first is that perception comes from the variety of receptors in the muscle/heart and lungs that are stimulated by physical changes during exercise. The receptors send something called afferent feedback to the brain that generates a perception of effort.

The theory I support is that how you perceive effort is based on the brain's central motor command – how forcefully the brain activates the muscle. If you block afferent feedback by injecting anaesthetic into the leg muscles, when you move you will not feel any signals or pain from them, but will still feel a perception of 'effort'.

What applications do you hope your research could lead to?
Working with patients affected by rheumatic diseases, kidney disease and cancer, which cause muscle wasting problems, the thing that limits their quality of life the most is often chronic fatigue. So I became very interested in their perception of effort. There is a lot known about the perceptions like pain and appetite and their physiology, but not fatigue.

Do you think your work on the perception of effort could lead to pain-free exercise, which could help reduce obesity?
Absolutely. If you can better understand and reduce the perception of effort you may be able to help increase the number of people taking exercise. Hopefully we will receive funding for this area of our research.

How did you get into physiology?
It started through sport and then I moved into physiology. When I was young I was a competitive athlete in basketball and American football. I was interested in how you can improve your training, your performance and your nutrition; you start to get into the physiology of it. During my PE degree we had to study anatomy, biochemistry and physiology, and so I became interested in it that way.

Has your work ever led to working with sporting greats or high-profile teams?
I've been scientific adviser to Mapei, a professional cycling team that in the early 2000s was the best in the world.

What other research does your team do?
In our sports performance group we look at fatigue and endurance in athletes. Our other group concentrates more on physical health and rehabilitation, involving both athletes and people like cardiac patients.

What do you like about sport physiology and what type of scientist does it suit?
We work with humans, not mice! I think it is good for people who like to see the direct application of science to humans. Much of my research is picked up by coaches and athletes, and knowing it has improved their lives gives me satisfaction.

Physiologists often work with athletes

Profession
Professor of exercise physiology and director of research at the Centre for Sports Studies, University of Kent

Qualifications
PhD in exercise physiology, MSc in human performance, BSc in physical education

Research interests
Neurophysiology of perceived exertion and endurance exercise performance; fatigue in clinical populations

If you can reduce the perception of effort, you may be able to increase the number of people exercising

Plant science

The modern, multidisciplinary study of plants

Inside the Palm House, Kew Gardens, London

Plant science is the modern, multidisciplinary study of plants, once better known as botany. It has developed from the collection and classification of plants, algae and fungi into a branch of the biosciences concerned with solving some of the world's most pressing issues.

Why is it important?

Green plants provide most of the world's molecular oxygen and by harnessing the sun's energy, sustain most of the Earth's ecosystems. They have been a crucial source of food, medicine and materials throughout human history.

Botany is no longer confined to the study of how and why plants grow in the way they do. Today plant scientists are responding to the critical challenges of the 21st century – ensuring food security for a growing global population; helping us adapt to and mitigate climate change; protecting biodiversity and improving global health.

What careers are available?

There is a shortage of plant scientists in the UK and many other countries around the world. Things are changing, however. Plant science is at the forefront of investment and research focused on growing more efficient and healthy food, developing sustainable agricultural practices, and producing green energy and products such as biofuels and bioplastics. Plant scientists contribute to a diverse range of key industries including agriculture, pharmaceuticals, forestry, food, and industrial biotechnology. According to a recent report on the industry, the sector believes that more plant scientists must be trained to help translate cutting edge plant science into useful applications across these industries. Other careers are available working in botanical gardens, zoos, museums or with sports turfs.

How do I get into it?

Botany degrees have largely been replaced by plant science courses, some of which are joint degrees combined with related subjects such as soil science, cellular biology or wildlife. Plant scientists can also take more general bioscience undergraduate degrees and specialise later in their academic careers. Degrees in horticulture and agriculture are also available from many universities in the UK, especially in more rural areas.

Where can I find out more?

The UK Plant Sciences Federation, one of the Society's special interest groups, represents the UK's plant science community.

- www.plantsci.org.uk

Science and Plants for Schools promotes plant science at school level and has information in studying it at university.

- www.saps.org.uk

There are many more organisations and charities around the world that have information on specific branches of crop science such as forestry, agriculture and food production. A list of links can be found on the Global Plant Council's website:

- globalplantcouncil.org/resources

FIRST PERSON

Dr Mark Spencer

What does your job involve?
My job is pretty diverse and complex by curatorial standards. I manage the 620,000 specimens of The British and Irish Herbarium, and use those materials to do research, mostly on environmental change. I represent the museum for a variety of public engagement work and in ensuring organisms that can control invasive species are effective. I also work closely with the museum's entomology experts to look at the interrelationship between the plants and insects in our collections.

Then there is my forensic case work. I help the police by analysing vegetation fragments to link suspects to crime scenes – mostly involving murder or attempted murder.

I am based in the museum at Knightsbridge 60% of the time, but my schedule is pretty fluid. With the forensic work, in particular, if I get a call I have to go, straight away. I may have to be at the crime scene for up to three days.

How much can you tell us about the forensic work you do?
The majority of murders are in the built or domestic environment. So the ones in open landscapes, where there is vegetation evidence, tend to be particularly horrific, or someone has gone to a lot of effort to hide the body. It tends to be seriously organised crime, or child murders. In other words, high profile cases that the public find very disturbing.

How did you get into plant science?
I think it's what they call a 'non-traditional' route. As a child I was obsessed with plants, but I went a bit crazy at secondary school and did not do well academically. I worked in a nursery and tried horticulture at Kew, but realised I hated gardening. I'd been reading degree-level texts on plants since I was 10, which should have given me a hint of what to do, but it wasn't until I was 27 after several years of dithering that I took a degree in botany. I went on to do a PhD in the systematics of aquatic fungi called *Peronosporomycetes*. I did a few years in field botany, as there are very few jobs in fungal taxonomy these days – that discipline has just been ravaged. Then I took roles in historical botany and curation.

Do you fear for the future of systematics and taxonomy?
In the UK it is just about holding its own, but we'll probably see a gradual and continued decline. In other countries like China it is relatively buoyant and there has been lots of investment. What's needed here is a fundamental change in how we view science and, unfortunately, we're a long way off that.

Where do you think plant science will be important in the future?
Using plant science to understand how plants respond to environmental change will be key. Perennial ryegrass, for example, is probably the most important grass in Britain – it's on football pitches, lawns, and the fields used to graze cattle. If it were to start disappearing it would be catastrophic. Without sounding too dramatic, there are some pretty significant changes to the biosphere round the corner. Hopefully we'll start to see people with knowledge of whole organisms, ecology, and plant biodiversity valued more.

Forensics at a crime scene

Profession
Senior curator, British and Irish Herbarium, Natural History Museum
Qualifications
BSc botany, PhD fungal systematics
Interests
Invasive species, climate change, fungal systematics

Murders in open landscapes, where there is vegetation evidence, tend to be particularly horrific

Zoology

The study of animals and how they behave, reproduce, evolve and interact

Despite our interest in them, mammals make up only a tiny fraction of the animal species on Earth

Zoology is the scientific study of animals, including how they behave, reproduce, evolve and interact with their environment. It is sometimes known as animal biology or 'whole organism biology' in contrast to other branches of biology that specifically study life at the cellular or molecular level.

It can be broken down into numerous sub-disciplines based on the study of particular types of animal: ornithology (the study of birds), primatology (the study of primates) or ichthyology (the study of fish) to name a few. It is a complex and broad subject encompassing a range of related disciplines and fields, including ecology, conservation, taxonomy, palaeontology, genetics and evolutionary biology.

Why is it important?

Zoological institutions often focus their efforts on the conservation of animal species and their habitats. Preserving and balancing delicate ecosystems and biodiversity is critical to humans as well as animals. Zoology enables us to better understand wildlife and our environment and – by studying behaviour, evolution and higher mammals – ourselves.

What careers are available?

Zoology graduates are employed in a wide range of career areas, including conservation, environmental and wildlife management, tourism, medical research, veterinary sciences, animal ecology, the media, teaching, and science policy.

Jobs are available with a variety of organisations in the public, private and not-for-profit sectors. Typical employers include zoos and wildlife parks; government agencies; environmental and animal charities; science centres, libraries and museums; and universities and research institutes.

How do I get into a career in zoology?

Studying for a degree in zoology provides many transferable skills valued by many employers, including data handling, analytical skills, and both laboratory and field research experience.

An A-level in biology is often essential to get onto a zoology or animal biology degree. Most universities offer a three year course, though some offer four year courses with a year's industrial placement. There are also joint honours courses, with related and completely unrelated subjects. According to The Complete University Guide, employment prospects are good and Imperial is the highest ranking university that offers zoology as a specific degree.

Where can I find out more?

The Zoological Society of London is an international scientific, conservation and educational charity. Its research division, the Institute of Zoology, specialises in scientific projects and training related to the conservation of animal species and their habitats.

● www.zsl.org

FIRST PERSON

Olivia Needham

As a conservation technology project coordinator, what do you do?
I use camera-trap technology to help monitor and research rare or endangered species. At the moment we are developing a project called 'Instant Wild' which sends you an email of the picture every time a camera trap is triggered.

Previously you might have 20 cameras running for six months, and at the end you would have hundreds of thousands of images on a card that someone had to go through and analyse. It could be very labour intensive and, before you knew it, your report was on a survey that was a year old. With disappearing species we can't afford to have that time lag, so this technology allows us to start analysing the data while the survey is still going.

What does a typical day involve?
I'm mostly office based, but I'm in constant communication with our teams in the field – Mongolia, Indonesia, Guinea, Kenya, Saudi Arabia. I help the teams with their survey designs and with setting up the technology – determining, for example, the best way to position and locate the cameras.

I spend a lot of time looking at and identifying pictures. A lot of them are pretty incredible, like when you spot a leopard in an area where one has never been pictured, ever.

What is it about your work that motivates you?
I think it's our lack of knowledge about where species occur. It really inhibits conservation work if we are ignorant about which populations are where and which ones are in decline. It's like a business – you have to understand your stock – what there's a lot of, what's running out, what's a priority. We need to find more efficient ways to understand wildlife and I think technology is the best way to do that.

We also spot poachers – I see a lot of photographs featuring people with guns. It's good to be able to keep up to date with what's going on in an area in real time.

Do you remember when or why you decided you wanted to study zoology?
I remember taking an environmental studies course in high school. It focused on indicator species and ecosystems. It just really hit home how everything is connected and how important something like a honeybee is for things like pollination and our food.

Do you think zoology attracts a certain type of person?
It's not strictly a research discipline – it's about understanding lots of interconnected things, and how animals interact with humans. So I think a deep understanding of socio-economic issues and how things are connected is important, as well as having a bit of a campaigning streak.

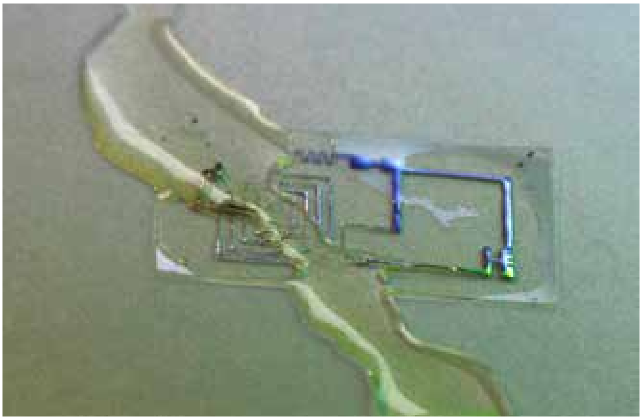
Camera trap technology was used to capture this image of a leopard, in an area where the animal has never been pictured before

Profession
Conservation technology project coordinator, Zoological Society of London
Qualifications
BSc environmental studies, University of Redlands, California. Masters in Conservation at UCL
Interests
The use of technology for researching species in conservation

We need to find more efficient ways to understand wildlife and I think technology is the best way to do that

Bioengineering

Combining engineering and biology to make new technology and medicine



Electronic circuits that dissolve in water or bodily fluids could be used as medical implants in future

Bioengineering applies the principles of engineering to biological and medical problems. It combines science, engineering, technology and medicine to create innovative devices, materials or processes for a diverse range of uses, but often related to improving human health.

Why is it important?

Bioengineering's most visible branch is the development of medical innovations such as prosthetics and high-tech implants, but genetic, stem cell and tissue engineering are all set to become key fields in the medicine of the future. Bioengineering also exists to advance the study and application of any biological research into useful systems or tools. It can translate biological knowledge into usable, economically viable products and practical solutions to 'real world' problems – from fuel and food production to environment and waste services.

What careers are available?

Some of the biggest employers are medical technology and imaging companies, such as Philips, GE and Siemens, and device and pharma companies such as Johnson & Johnson and GSK. The NHS and hospitals also require bioengineers to help develop and improve medical devices. Bioengineers also work at the cellular and molecular level, with genetic engineering, synthetic biology and nanotechnology an increasingly rich area of research and industrial applications.

Computer scientists are required to design the electronic circuitry and software for lots of bioengineered tools. There are also numerous auxiliary careers in the design, sale and marketing of bioengineered products and services. Biomimetics is a more niche field that uses the structure of living things as inspiration for the design of materials, buildings and machines.

In the US, *Forbes* magazine named biomedical engineering as the most valuable degree to take, and CNN Money voted biomedical engineer 'best job in America' in terms of pay and job satisfaction.

How do I become a bioengineer?

There are a growing number of accredited undergraduate and postgraduate bioengineering courses in the UK. Often these are called biomedical engineering, but can be referred to as bioengineering or medical engineering. Some bioengineers study more general engineering, mechanics, physics or computer science before focusing their education and research on biological applications through postgraduate master's or research programmes of study.

Where can I find out more?

The American Institute for Medical and Biological Engineering
- http://navigate.aimbe.org

The Biomedical Engineering Society
- http://bmes.org

A number of UK engineering institutes support bioengineers, including:

Royal Academy of Engineering Panel for Biomedical Engineering
- www.raeng.org.uk/policy/engineering-policy/panel-for-biomedical-engineering

Institution of Mechanical Engineers Biomedical Engineering Association
- www.imeche.org/knowledge/industries/biomedical

Institute of Physics and Engineering in Medicine
- www.ipem.ac.uk

The largest UK meeting for bioengineering is MECbioeng
- www.mecbioeng.org

FIRST PERSON

Dr Zhen Ma

What does an average day in a tissue engineering lab involve?
I have to take care of my cells every day – it's like having a puppy. The first thing I do when I get here is to feed them. And cell culture medium is expensive food.

What is your lab working on?
Using stem cells, my colleagues create 'organ on a chip' microsystems to mimic different types of human tissue for drug screening and discovery. We can study how, for example, heart or liver microtissues react to drugs, and try to replace animal models. It's good to reduce the use of animals in research and drugs tested on animals still need to be tested on human tissue anyway.

I work specifically on heart cells: I create three-dimensional diseased cardiac tissue. Cells grow along a filamentous matrix of tiny fibres that mimics the way heart cells grow *in vivo*, where they align in one direction. The 3D structure makes it much more sensitive to the drug treatment than previous 2D systems.

What other interesting things are going on in the lab?
My colleagues are working on hydrogels, which are special biomaterials that can be injected into the heart to act like a sort of self-healing patch to encourage stem cells or tissue to regenerate. New cells grow on the heart to repair damaged tissue.

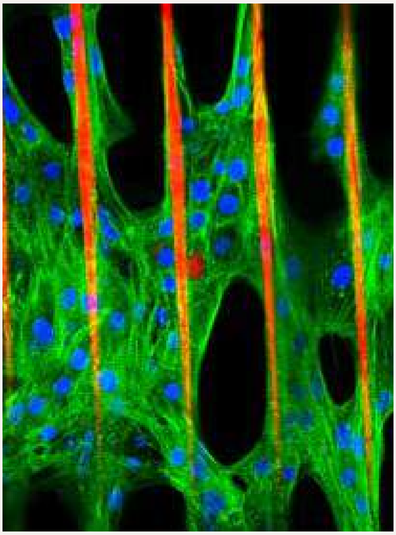
What do you enjoy about bioengineering?
Tissue engineering is really exciting and I really want to continue working in this field. It's so multi-disciplinary: we have chemists, computer scientists, engineers and biologists all working here.

Some of the other scientific projects are so big that you can't work by yourself; there's lots of sharing of expertise and collaboration. With my projects, I often sit with mechanical engineers to help work out how we can move forward. The matrix on which I grow the heart cells was fabricated by the engineering department, for example. The special fibres are just 5 microns (0.005mm) thick.

Have you found biology and engineering approaches differ?
The difference between biologists and engineers is that the biologist says 'how does this work?', while the engineer says 'OK, we know this works, so how can we make it better to work for us?'

It's interesting how people become bioengineers. My undergraduate degree was in electrical engineering, then I did a master's on instruments to detect glucose levels in blood, and then became more and more interested in bioengineering.

What excites you about bioengineering in the future?
The area I think is really hot right now is genomic engineering, where you change healthy cells to become diseased to study how those cells progress. Bringing that technology and stem cell and tissue engineering technology together could have a huge impact on human healthcare.



A micrograph of cardiac microtissue, showing artificial fibres (red), cardiomyocyte cell bodies (green), and cardiomyocyte nuclei (blue)

Profession
Postdoctoral associate, Healey Laboratory, University of California, Berkeley, US
Qualifications
PhD (bioengineering) Clemson University; MSc (bio-instrumentation) Tianjin University, China; BSc (engineering) Tianjin University, China
Interests
Stem cell biology and engineering, 'heart on a chip' technology, biomaterials

We can study how heart or liver microtissues react to drugs

Clinical trials

Biomedical or behavioural research studies on human subjects

Clinical trials help to ensure that medicines on the market are safe

Clinical trials make up the crucial final stages of the development of all regulated drugs and therapies. Extensive biomedical or behavioural studies on human subjects determine the safety and efficacy of any treatment before it is approved for use as medicine.

Why is it important?

Failure to fully investigate the safety of promising drugs has had devastating consequences throughout history. Most memorably thalidomide was once widely prescribed to alleviate morning sickness in pregnant women, but caused abnormal limb formation in thousands of their children. Clinical trials can take years to report and cost many millions of pounds, but ultimately they give us confidence that the medicines we take will improve our health, safely.

What careers are available?

Clinical trials are usually conducted by government health agencies or pharmaceutical, biotechnology or medical device companies, but also by independent research organisations, hospitals or academic research units. A multitude of public bodies – such as the Medicines and Healthcare Products Regulatory Agency and the National Institute for Health and Care Excellence (NICE) in the UK – regulate clinical trials and the use of approved drugs.

Careers are available at all stages of the drug approval process, from lab-based research roles in small, early phase pilot studies, to the design of huge trials involving real patients in institutions spread across many countries. Trial managers are required to organise these complex trials (see opposite) while teams of statisticians analyse and interpret trial data. Other opportunities around the world are dependent on how healthcare is administered. In the UK, for example, NICE helps interpret data from a range of sources, including clinical trials, to advise the NHS on what therapies are most cost-effective.

Where can I find out more?

The Medical Research Council's website has a section on careers and training in research roles and information on studentships, fellowships and funding.
- www.mrc.ac.uk

The UK Clinical Research Collaboration's Clinical Trials Network provides information for researchers and funders.
- www.ukcrc.org

The UK clinical trials gateway provides information on all trials running in the UK as well as useful links to organisations that run trials.
- www.ukctg.nihr.ac.uk

Clinicaltrials.gov currently holds information on 164,703 studies in 185 countries around the world.
- clinicaltrials.gov

FIRST PERSON

Claire Snowdon

Profession
Deputy director of operations, Clinical Trials and Statistics Unit, Institute of Cancer Research
Qualifications
BSc zoology, MSc ecology
Interests
Clinical trial methodologies

What does a typical day involve?
In our unit we design, develop and analyse clinical trials for cancer treatments. When clinicians have a concept for a trial, we advise on the statistical design and develop the complex logistics for its delivery. We then oversee the conduct of the trial, collect data from the participating hospitals and analyse the results.

I work with lab scientists, clinicians and statisticians – locally and nationally – as well as funders and regulators. There's lots of liaising to make sure that the trials are of the highest scientific quality and safety standards. I also work with various lobby groups to ensure EU legislation on clinical trials is not overly bureaucratic and does not delay novel treatments unnecessarily. Much of the trial management role is logistics: how do we get samples from 100 hospitals to one centre for analysis? A trial concept may be scientifically very interesting but logistically challenging to fit within the typical care pathways in the NHS.

How did you come to work in clinical trials?
I did a degree in zoology, then a master's in ecology, and didn't really know what to do. I took a research assistant's job at The University of Manchester, which is when I first worked on clinical trials. I then worked on clinical trials in industry and moved back to academia, working for Imperial College London before coming to the Institute.

People are aware of drug research in the pharmaceutical industry, but don't know there is an equivalent academic career path available. A lot of scientists get to a certain point and think they don't want to spend the rest of their life working in a lab. Clinical trials allow you to stay in biomedical research, but much of it is office-based, with visits to hospitals, labs and research facilities in the UK and abroad. We are looking to promote clinical trials in university settings as a career option.

Is it a rewarding job?
Working on a huge experiment for the benefit of cancer patients is rewarding. Clinical trials can take a long time to report, not all are successful and it can be very bureaucratic – but you can see them making a difference.

Has there been a trial you've worked on that had a positive outcome?
Yes, patients with hormone sensitive breast cancer were typically treated with tamoxifen to stop it coming back. It is an effective drug, but doesn't work for everyone. We trialled treatment that involved switching to aromatase inhibitors, after two to three years of treatment. It improved disease free survival and went on to influence how breast cancer in postmenopausal women is treated.

As drug screening technology improves, will the nature of the trials change?
Pre-clinical trials may change greatly, but you will always need to put treatments into a patient population.

The Institute of Cancer Research's trials can involve up to 150 hospitals

Working on a huge experiment for the benefit of cancer patients is rewarding

Endocrinology

The study of hormones

The thyroid helps control how the body reacts to other hormones

Endocrinology is the study of hormones. At its simplest, a hormone is a chemical messenger from one cell, or group of cells, to another. Hormones are released (secreted) and have an effect on other parts of the body. Hormones are found in organisms with more than one cell, and are therefore found in all plants and animals.

Why is endocrinology important?
Hormones influence or control a wide range of physiological activities, such as growth, puberty, sugar regulation and appetite. Problems with hormones and the way they work contribute to some of the major diseases of mankind. These include diabetes, thyroid conditions, some sexual problems, appetite and obesity and cancer. Endocrinologists work to understand hormone function and treat these conditions.

How do I get into endocrinology?
Currently, there isn't an undergraduate degree course in endocrinology and so those working within the field arrived there through a variety of routes.

For example, a degree in medicine allows you to specialise in endocrinology and then follow a clinical academic pathway. Alternatively, you might complete an undergraduate degree in a biological science and then carry out postgraduate and postdoctoral research in endocrinology.

What can I do with endocrinology?
Endocrinology encompasses many areas of our life and work. Endocrinologists are employed as drug developers in the pharmaceutical industry, or as toxicologists, academic researchers, laboratory researchers, nurses, vets, doctors, environmentalists or clinical biochemists.

Where can I find out more?
The Society for Endocrinology provides information on endocrinology and endocrine careers.
- www.endocrinology.org

More general information about hormones and endocrine science can be found at the Society for Endocrinology's You and Your Hormones website.
- www.yourhormones.info

FIRST PERSON

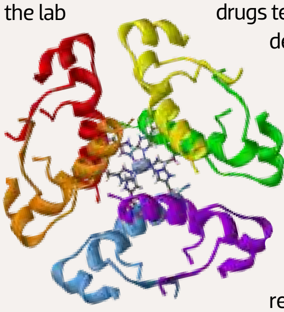
Dr Kevin Murphy

What does your job involve?
My job revolves around research, teaching and administration.

What is the focus of your research?
My major focus is obesity. I'm interested in the physiological mechanisms by which appetite is regulated, particularly those that could be targets for anti-obesity therapies. I want to hijack the mechanisms that make us feel full after we've eaten and use that as a treatment for obesity.

What did you study at university?
A BSc in physiology and zoology. We studied some basic endocrinology, but what really got me into it was working as a technician after my degree, in the lab where I currently work.

What made you decide to specialise in endocrinology?
The neuroendocrine regulation of obesity is a big problem, so there's public interest and there's also funding available.



Human insulin hexamer 3D ribbons

What advice do you have for budding endocrinologists?
Focus on an area you're interested in because it is hard work and the hours are long. A successful career is not necessarily about having brilliant ideas all the time. What you really need is one solid idea you can convince people is worth funding.

Are there any other hot topics in endocrinology at the moment?
Reproductive endocrinology is interesting. The discovery of a neuropeptide called kisspeptin was a shot in the arm for the field. Kisspeptin has such a big effect on the reproductive system that a lot of people are very interested in it.

What is your favourite hormone?
I've got a soft spot for peptide YY. It's released from the gut after a meal and it signals to the brain to reduce appetite.

Where is endocrinology headed?
We're going to become more integrated with other disciplines. There's also going to be a lot of interest in whether we can target molecules to specific cell types.

Do you think we'll see a cure for obesity?
Drug development takes a long time because safety is paramount. You have to be very careful about side effects because you don't want to make people sick when they're ostensibly well. What we'll probably end up with is a combination of drugs rather than a single golden bullet, and combining drugs tends to lengthen the development time required.

Would some side effects be acceptable given the health risks of obesity?
Most people would say "no" at the moment, partly because previous anti-obesity drugs haven't reduced body weight very much, but have had side effects. If we came up with a drug that really reduced body weight and the risks associated with being obese, people would be more willing to tolerate certain side effects.

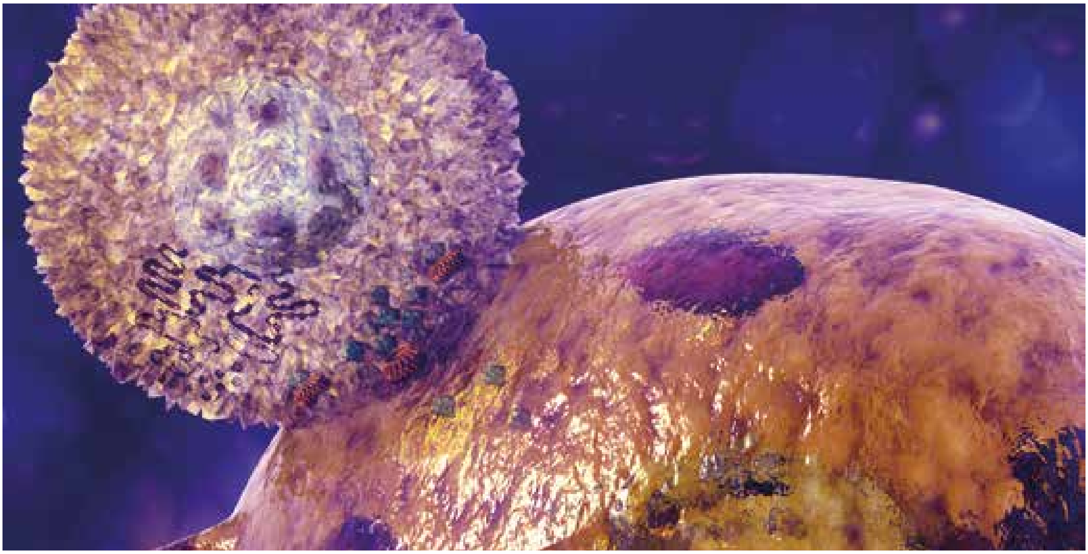
Endocrinology also hits the headlines when chemicals that disrupt the endocrine system are found in the environment. What effect do these endocrine disruptors have in the body?
The major worry is that chemicals act as though they are hormones, so they cross-react with, for example, oestrogen receptors. We don't really know how big a problem it is, but there is evidence that they are effective. As environmental law and chemical regulation become tighter, hopefully we won't just have these things sloshed into the water supply willy-nilly.

Profession
Reader in endocrinology
Qualifications
PhD, BSc (Hons) in zoology and physiology, Certificate of Advanced Study in Learning and Teaching
Research Interests
The control of appetite and body weight, and how the gastrointestinal tract communicates with the brain to regulate food intake. The role of kisspeptin in reproduction

I want to hijack the mechanisms that make us feel full after we've eaten and use them to treat obesity

Immunology

The study of the immune system



Natural killer cell attacking an infected cell

Immunology is the study of the immune system in both healthy and diseased states. It includes the study of how the body fights infections from bacteria and viruses and the development of medical interventions to treat and prevent diseases.

Why is immunology important?

The study of immunology is critical to human and animal health and survival. It is at the cutting edge of medical science and has led to some key healthcare advances of recent times, including vaccination and cancer immunotherapy.

Immunologists are developing new treatments to some of the major diseases affecting mankind, including infectious diseases (such as influenza and Ebola), autoimmune conditions (such as type 1 diabetes) and a variety of cancers. The immune system is incredibly complex and we still have lots more to find out about how it works.

What careers are available?

Immunologists work in many different sectors. You can find immunologists working as scientists in universities, as drug developers in the pharmaceutical industry, as clinical scientists in the healthcare system or as clinicians, nurses and vets, to name but a few.

How do I get into a career in immunology?

There are many routes to becoming an immunologist. The standard path is to study for an undergraduate degree in immunology or a related bioscience subject, followed by postgraduate study (such as a PhD), focusing in more depth on a particular aspect of the immune system. However, some people choose to go straight into work after their undergraduate course and gain additional qualifications while working.

As the discipline of immunology becomes more complex, it is increasingly utilising interdisciplinary skills from other sectors, such as computing and bioinformatics. This means there is now increased collaboration between researchers from different fields working on immunology focused projects.

Where can I find out more?

The British Society for Immunology provides careers information.

- www.immunology.org

More general information on immunology can be found on their Bite-Sized Immunology website.

- bitesized.immunology.org

FIRST PERSON

Emily Gwyer Findlay

What do you do?
I work on antimicrobial peptides – molecules that are found all over the body, in every bodily fluid. It was once thought that these peptides just kill bacteria directly by drilling holes in their cell walls, but it is now thought they have a wider role in the body's immune response. I'm looking at whether they are antiviral as well as antibacterial.

The work of the lab is particularly relevant because of the increasing problem of antimicrobial resistance – antimicrobial peptides could be an alternative way to control infections in the future.

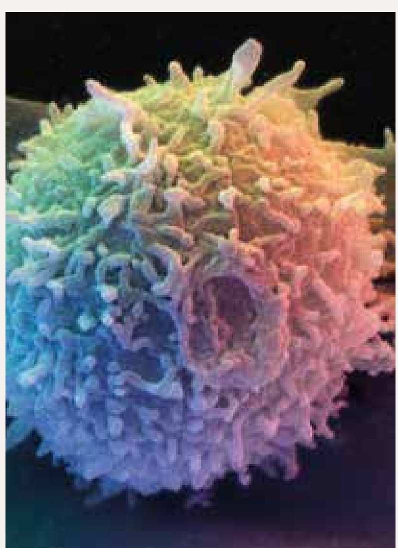
What does an average day involve?
It's all lab work. We treat animal and human cells with antimicrobial peptides and see if it helps their defence against lung infections. I get in early at about 7am and set up the day's experiment – running an analysis or PCR – then I have my coffee and answer emails, before working with my mice.

What other areas of immunology interest you?
I am a specialist in T-cells, white blood cells that respond to infections. I have previously looked at their role in diseases such as arthritis and malaria. In arthritis we found that if you could block them from accumulating in the inflamed joints you could block the development of the disease.

How did you become interested in immunology?
I actually did a biochemistry degree and master's, but really enjoyed my module on immunology, so I asked my course tutor if I could do a PhD and she said yes. I don't like dry chemical equations and with immunology you could see how it could help people. It's exciting, too: there's always loads of new data being produced and experiments have fast turnarounds.

Immunology is known for being incredibly complicated. Would you agree? And does it attract a certain type of person?
It is very complicated. I spend a huge amount of time reading – something will happen that no one has ever seen before and then you have to read 50 other papers just to understand what's going on. I think it attracts big-picture thinkers, rather than people who like to focus on very specific problems for a long time.

What do you think will be exciting about immunology in the future?
At the moment everything is changing as the techniques we use advance rapidly. In particular, the way we detect bacterial species – by sequencing rather than trying to grow them – has meant we're suddenly understanding the massively important role our commensal flora have in immune responses to pathogens. This is hugely interesting and the big growth area at the moment, and something we are all trying to understand.



Coloured scanning electron micrograph of a T-lymphocyte or T-cell

David Scharf/Science Photo Library

Profession
Senior postdoctoral researcher with Dr Donald Davidson at the MRC Centre for Inflammation Research, The University of Edinburgh

Qualifications
Combined BSc and MRes Biochemistry, Imperial College London; PhD on T-cells and inflammatory diseases, Imperial College London

Interests
T-cells, antimicrobial peptides, *in vivo* models of infection

I have looked at the role of T-cells in diseases such as arthritis and malaria

Neuroscience

The study of the nervous system

Learning about the nervous system helps scientists develop treatments for diseases

Neuroscience is the study of the nervous system, which includes the brain, the spinal cord and networks of sensory nerve cells (neurons) throughout the body.

Why is neuroscience so important?
Understanding the nervous system is important as it enables scientists to develop better treatments for neurodegenerative diseases, such as Alzheimer's, and for mental illnesses.

It is also important for scientists to learn more about how the nervous system functions under normal circumstances as it will enable us to appreciate what happens when things go wrong.

What careers are available?
Neuroscientists are today involved in much broader areas of study than before, including cellular, functional, evolutionary, computational, molecular and medical aspects of the nervous system. It is a field that integrates many aspects of science including biology, chemistry, physics, physiology, anatomy, and the study of emotional and cognitive functions. As such, there is a diverse range of jobs available within the field, including research, hospital and pharma careers.

What is the best way to pursue a career in neuroscience?
There are many ways to get into a career in neuroscience. The standard career route tends to be via a PhD, followed by postdoctoral research or a medical doctorate and then finally specialising in neuroscience.

The choice of first degree prior to PhD is vast, including neuroscience, physiology, genetics, mathematics, physics, chemistry, computing and molecular biology.

Where can I find out more?
Further information can be obtained through career advisers at school or university or through a number of learned societies, including:

The British Neuroscience Association
- www.bna.org.uk

The International Brain Research Organization
- ibro.info

The International Society for Neurochemistry
- www.neurochemistry.org

The European Brain and Behaviour Society
- www.ebbs-science.org

The Society for Neuroscience
- www.sfn.org

FIRST PERSON

Dr Zarinah Agnew

What are you doing at the moment?
I'm on a fellowship at a hospital in America as part of my postdoctorate with UCL – it's a clinical project at the University of San Francisco. I'm looking at patients with cerebellar ataxia, so mapping the brains of people with damage to their cerebellum. Patients with ataxia will often struggle to point to a target because their lesion affects the visual and sensory feedback coming back from their limbs. I'm researching whether these patients also have a deficit in the movements associated with speech because of problems with auditory feedback.

So your research may help to develop therapies for people with cerebral lesions?
Yes, ultimately, but my research is very basic science – it's early days. The idea is that if we can understand the brain in a strategic way in healthy people we can do more to help those with certain conditions. Dexterity in these movements is highly advanced in humans and it is likely that our ability to make complex movements with our hands and mouths has been a major part of our evolutionary history – they have allowed both tool use and the development of speech. Unfortunately, they are movements that are commonly affected by stroke, so the deficits that these patients sustain have a great deal to teach us about how brains are organised.

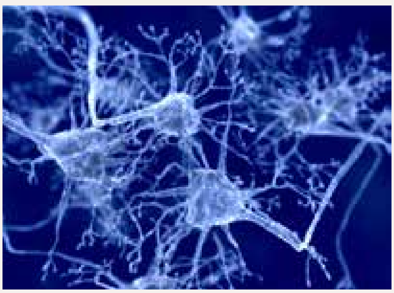
Describe your typical working day.
In London I work in a research institute and specialise in MRI scanning, but I also use MEG (magnetoencephalography) scanners and use transcranial magnetic stimulation a lot to interrupt brain function.

It's very phasic – you work really hard running these experiments and then you stop and analyse the data and do lots of writing. That's nice because you can structure your time in a way that suits you – it's a real luxury, actually, to wake up and think "today I feel like writing" and being able to do that.

How did you get into your current career?
I did a degree in neuroscience which is actually quite rare and is not necessarily advisable. I did a master's in integrative neuroscience and then a PhD, but most people come into this sort of research from a physiology or life sciences career. You have your whole career to specialise so it's not necessary to specialise in your first degree. I realised this was something I wanted to do from an early age, but it means I've been studying neuroscience forever.

Why did you want to study neuroscience in the first place?
Even as a teenager, I was struck by how little we knew about the brain – at that point there was nothing taught in schools. I decided that I wanted to understand how brains produce the human experience that we perceive as everyday life. At sixth form college I had a good biology teacher who encouraged me. She taught me about the action potential, and how it is propagated down a neurone, and that was that – I was hooked.

What sort of person makes a good neuroscientist?
I don't know about neuroscience, but to be a good researcher is all about passion. Dedication and intelligence too, but passion is important. It's very rare in this job that you meet someone who is lazy – why would you be doing this if you weren't passionate about finding out what you've set out to find?


Understanding of neurons is changing rapidly

Profession
Neuroscientist at University College London (UCL)
Qualifications
PhD Imperial College London, MRes integrative neuroscience from University of Manchester, BSc (Hons) neuroscience, University of Manchester
Interests
The control of complex voluntary movement, especially the movement of the upper limbs and of the articulators

To be a good researcher is all about passion. Intelligence too, but passion is important

Nutrition

The study of the effect of diet on the body

Nutrition focuses on the interaction of the diet with the body, and how this impacts on health, wellbeing and development. It also includes factors that determine food choice, including the quality and quantity of dietary intake. Nutrition therefore encompasses a broad range of disciplines, from sociology and psychology through food production and food science to biochemistry, molecular biology, chemistry and physics.

Why is nutrition important?

Our diets and the nutrients they provide directly impact growth and development in childhood, and mental and physical health throughout our lives. Under or overconsumption and/or habitual high or low intake of certain nutrients or food groups can affect the risk of many chronic conditions such as obesity, type 2 diabetes, hypertension, cardiovascular diseases and cancers. Many people in developing countries have inadequate intake of energy or specific nutrients such as vitamin A – still the major preventable cause of blindness worldwide.

How do I get into nutrition?

The recommended route is through studying a degree in nutrition or one of the specialist areas within the field, such as public health nutrition, sport and exercise nutrition or dietetics. Many will choose to specialise during postgraduate study. Appropriate courses are accredited by the Association for Nutrition (AfN).

Where can I work?

The broad range of fields includes: academia or research organisations (basic science through to public health); health promotion within the NHS or local authorities; charities or non-governmental organisations; policy development working for the Department of Health, the Food Standards Agency (in Scotland and Northern Ireland) and the Department for Environment, Food and Rural Affairs; the food industry and retail sector developing new products or resources or being involved in policy and strategy; agriculture (including animal nutrition, plant science and the food chain); sports nutrition; science writing or freelance consultancy.

Where can I find out more?

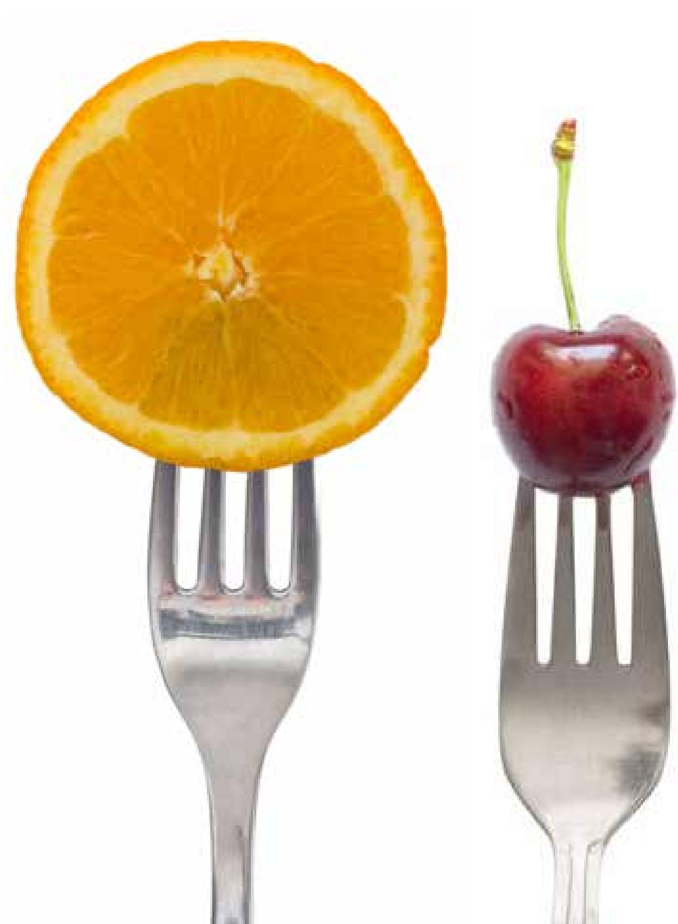
The Nutrition Society hosts regular conferences and publishes four journals on various aspects of nutritional science, including the *British Journal of Nutrition,* and *Public Health Nutrition*.

● www.nutritionsociety.org

AfN is the voluntary regulator for qualified nutritionists. It promotes nutrition and public health and maintains a register of individuals who are qualified in nutritional science and agree to uphold professional and ethical standards through a code of conduct.

● www.associationfornutrition.org

Food choices directly affect development, health and wellbeing



FIRST PERSON

Professor Julie Lovegrove

What does your job involve?
My work varies from basic research and teaching to acting on external national committees which advise the Government on nutritional policy.

What's the focus of your research?
It focuses on the impact on cardiovascular disease-risk of diet and lifestyle. I'm interested in dietary components including fats and carbohydrates, and how they reduce risk factors such as plasma lipid levels, insulin resistance and blood pressure.

What did you study at university?
I studied nutrition and dietetics because that was a perfect match between my interests in the way diet affects our bodies and in promoting health. During my degree I trained as a clinical dietician in a hospital, but I was more interested in understanding the role of nutrition in health and this led to a PhD in nutritional biochemistry.

What made you specialise in nutrition?
I've always had a passion for science and food. Nutrition is unique because we all eat and what we eat is important in promoting health and preventing disease. We need to try to prevent the development of chronic diseases such as cardiovascular disease and diabetes before they progress to a stage where medical attention is required.

Do you have any advice for budding nutritionists?
Get a good grounding in science – chemistry, biochemistry and physiology underpin the study of nutrition. If you want to practise clinical nutrition or be a dietician you need to study dietetics. There are also opportunities in industry, research and academia.

What are the hot topics in nutrition?
At the moment we have one-size-fits-all population-level recommendations for changing diet to promote health, but we're moving to a personalised approach where therapies are tailored to an individual's needs and risks. The interaction between diet and genes is very important, and an expanding area of research.

Where is nutrition headed as a subject?
Nutrition in relation to health and disease will continue to be important. Interdisciplinary research is also important – I collaborate with colleagues from varied fields, including psychology and mathematics. Collaborating has enabled us to study behaviour in relation to dietary modification, and detailed models of nutrient related pathways.

Do you think nutrition science is reported well in the media?
Nutrition is badly and often incorrectly reported because sensational headlines often take priority over facts. Everyone thinks they're an expert, and some people out there are not qualified to report or discuss nutritional issues. I am collaborating with the Association for Nutrition, which has established a professional register for qualified nutritionists.

Can nutrition solve the obesity epidemic?
Diet plays a very important part in obesity development and treatment, but shouldn't be considered in isolation. Diet and physical activity should go hand in hand in tackling obesity. Other factors also need to be addressed, such as genetic links and psychological barriers to dietary change.

Do vitamin supplements do any good?
Supplements may be required if someone is ill or has a specific disease, such as anaemia. But in the general population, a balanced diet should be enough.

Does food labelling lead consumers to make healthier choices?
Some food labels are far from helpful and there are no standards for consistency. If the clarity of food labels is improved, then hopefully they will become a useful tool for dietary modification.

Profession
Professor of metabolic nutrition, University of Reading
Qualifications
PhD in nutritional biochemistry; BSc nutrition and dietetics; registered nutritionist (RNutr)
Interests
Impact of diet on cardiovascular risk in different population groups

The interaction between diet and genes is very important and an expanding area of research

Parasitology

The study of the interaction between parasites and their hosts

Pediculus humanus, a louse that infests humans

Parasitology is the study of the interaction between parasites and their hosts. In general, parasitologists tend to concentrate on eukaryotic parasites, such as lice, mites, protozoa and worms, with prokaryotic parasites and other infectious agents the focus of fields such as bacteriology, microbiology and virology. Parasites are extremely common, and are responsible for some of the world's most deadly illnesses, from dysentery and diarrhoea to malaria.

Why is it important?

It's estimated that at least half of all known species are parasitic, so understanding the life cycle and interaction of these organisms with their hosts is often key to understanding the dynamics of ecosystems generally. Parasites cause millions of deaths and billions of infections in humans every year, but parasites of crops and animals can have equally devastating effects by disrupting global food supplies and people's livelihoods.

Parasites are hugely diverse. From the well-known cuckoo, which hides its eggs in another bird's brood, to the horrific parasitic crustacean Cymothoa exigua, which destroys the tongues of fish and attaches itself where the tongue once was, the strategies parasites employ to exploit their hosts are often remarkable. Over a hundred species of fungi alone have evolved to manipulate the behaviour of ants, including one that causes the 'zombiefied' ant to climb a tree, die and release spores onto its fellow workers below. There are even parasites of these ant parasites, known as hyperparasites.

What careers are available?

Parasitologists are largely employed by public health bodies and research organisations to evaluate treatments, prophylactics and vaccines that prevent parasitic infections. Biotech companies and the pharmaceutical industry need parasitologists to help treat parasitic disease in humans, to prevent losses in agriculture and aquaculture, and to keep people's pets free from worms and fleas.

Just like bacteria, parasites can develop drug resistance, so understanding their genes, proteins, life cycle and evolution through research is also important in controlling infections and predicting future outbreaks. Many parasitologists will work in or visit developing countries, and there are also opportunities in charity and policy roles because of the field's links to international development.

How do I get into it?

Many parasitologists progress into research careers after specialising at master's or PhD level. The majority of parasitology courses are at postgraduate level; common courses include medical parasitology, molecular parasitology and vector biology. A few institutions, such as the University of Glasgow, offer parasitology degrees.

Where can I find out more?

The British Society for Parasitology represents the UK community of parasite researchers.

- www.bspuk.org

FIRST PERSON

Dr Emily Adams

What does your job involve?
I develop new tests to detect parasites, train people how to perform new diagnostic tests and to see how effective these are compared with more traditional procedures. I am involved in the development of simplified molecular tools to sensitively test for Kinetoplastida diseases such as leishmaniasis and trypanosomiasis.

So you don't just look down a microscope for these parasites any more then?
No. Microscopy has saved many lives and has been an excellent diagnostic tool, but you need skilled operators and it is easy to miss a low number of parasites. Molecular tests can give more accurate and rapid results. Most of them involve detecting the parasite's DNA in the blood.

How are these diseases spread?
They are both protozoa, spread by flies. Leishmania is spread via sandfly bites and causes a spectrum of illnesses and up to 50,000 deaths a year. Trypanosomiasis, or sleeping sickness, is caused by trypanosomes delivered in tsetse fly bites.

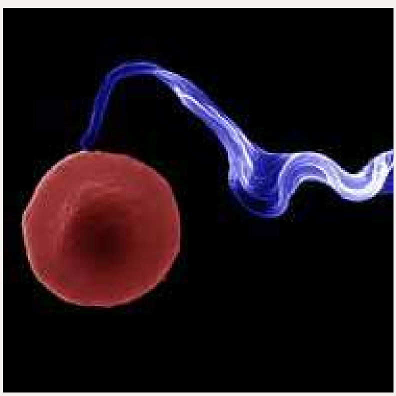
What does your typical day involve?
I'll usually have a Skype conversation with a project coordinator abroad and check how the enrolment of patients and results are going. Then I'll work on writing up a project for publication or peer reviewing other manuscripts. I don't work in the lab so much now, but I do train people and oversee the ethics of our experiments. I am meeting with the Gates Foundation soon to discuss diagnostics for tropical diseases.

Is public health, and saving lives, what attracted you to parasitology?
Absolutely. It's about taking the technology we have here in the West and making it cost effective and simple enough to use in an endemic setting.

How did you get to where you are now?
My PhD was developing molecular tests to differentiate between types of trypanosomes. I then worked in Amsterdam at the Royal Tropical Institute developing and evaluating diagnostics for diseases such as leishmaniasis. My current role is a joint appointment between the Liverpool School of Tropical Medicine (LSTM) and Warwick University.

Have you encountered lots of other strange tropical parasitic diseases while working at the LSTM?
There have been a few programmes that showed some of the highlights of LSTM, the really weird stuff. There are some fabulous parasites out there, with great examples of the weird and wonderful in nature. We have the Well-Travelled Clinic where people can come in and get their vaccinations before they go off on holiday. If they come back and they are feeling unwell, they can give us some samples, sometimes revealing a parasitic infection.

What do you think will be important for the field in the future?
There are 17 neglected tropical diseases specified by the World Health Organization and there will be a lot of work being done to try to eliminate them.



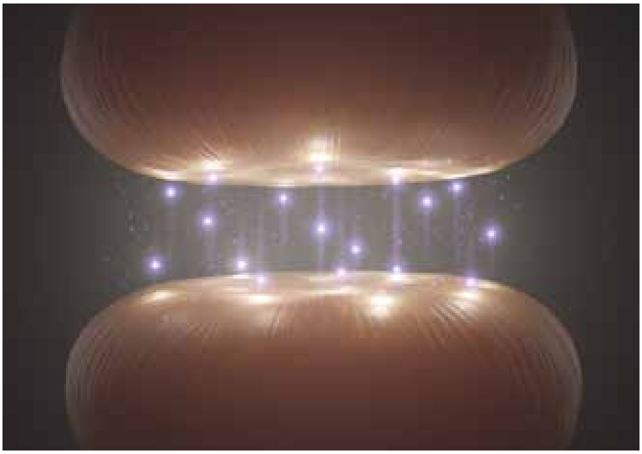
A trypanosome next to a human red blood cell

Profession
Lecturer in tropical diagnostics, Liverpool School of Tropical Medicine and University of Warwick (joint appointment)
Qualifications
BSc, MSc biosciences, PhD in molecular parasitology
Interests
Evaluation and implementation of diagnostics, and kinetoplastid diseases

Most molecular tests involve detecting a parasite's DNA in the blood

Pharmacology

The study of how medicines and other drugs work and are processed by the body



A digital illustration of neurotransmitters crossing a synapse, a system which many drugs target

Pharmacology studies how medicines and other drugs work and how they are processed by the body. Linking chemistry, physiology and pathology with many other disciplines, pharmacology is crucial in medicine and other life sciences.

Why is pharmacology important?

Drugs affect all of us in one way or another, through the medicines that we take, the problem of drugs in sport, the everyday consumption of alcohol and caffeine in drinks, environmental pollution and many other aspects of modern life. Pharmacology is vital for discovering new medicines to help fight common diseases such as cancer, depression and heart disease, as well as many other serious diseases. It is also essential for understanding the unwanted side effects of medicines, the reasons why individuals differ in the way they respond to drugs and why some drugs cause addiction.

Pharmacology improves the lives of millions of people across the world by providing vital answers at every stage of medicine discovery, testing and clinical use.

What types of career are available?

Pharmacologists make a unique contribution to today's science and tomorrow's medicines in universities, government agencies, the health service, and the pharmaceutical and biosciences industries.

Pharmacologists carrying out research broadly work in one of three settings: academia, industry or healthcare. Academic and industry pharmacologists conduct basic research in a lab into how drugs and medicines work, sometimes using animal models of disease. Clinical research pharmacologists help to translate basic pharmacological research into medicines ready for use. There is also a medical specialty called clinical pharmacology and therapeutics, which trains medical doctors to specialise in the safe and effective prescribing and use of drugs. Many pharmacologists go on to careers outside the lab, in fields such as scientific publishing, teaching, science communication, science policy and regulatory roles in the drug discovery industry.

How do I get into a pharmacology career?

Most pharmacologists will have started their career with an undergraduate degree in pharmacology or a related life science such as biochemistry or physiology. Those who wish to continue in research, whether in an academic or industry setting, may also undertake postgraduate study at master's or PhD level, although some pharmacologists working in industry will be employed directly at graduate level. Many scientists come to the discipline of pharmacology from other, related fields.

To become a clinical pharmacologist in the health service, you will need to have studied for a medical degree before specialising in clinical pharmacology and therapeutics.

Where can I find out more?

The British Pharmacological Society is a Member Organisation for pharmacologists and offers information and support about studying and working in pharmacology.

- www.bps.ac.uk/careers

The Association of the British Pharmaceutical Industry has a range of careers information available, including case studies.

- careers.abpi.org.uk

MRC Toxicology Unit, Wellcome Images

FIRST PERSON

Steve Trim

What does your company do?
As the name suggests, Venomtech produces venoms – mainly for drug discovery companies to develop into tools for research or therapeutics.

Why is venom so useful from a pharmacological perspective?
There are 15 drugs on the market that are venom-derived or 'peptomimetic' – ie, they have been created to function in the same way as an existing venom peptide. The main reason is that there has been selection pressure for millions of years on them hitting their targets. The fer-de-lance or pit viper's venom, for example, causes a catastrophic drop in blood pressure. But it provided the basis for the development of ACE-inhibitors, which have been very useful in the treatment of hypertension. There is also a type of cone snail venom licensed to treat chronic pain. The snail has evolved the venom to inhibit fishes' motor signals and stop them swimming away, but it also appears to inhibit pain sensors in humans.

Every species' venom is different to some extent – sometimes it is just a single amino acid difference in the peptide sequence. So we are building a natural library of all these variations and mutations.

How many species of venomous animal are there?
Tens of millions we think. There are 930 species of tarantulas alone, and 20,000 spiders, and almost all of them have venom. There are also many scorpion species, and tens of thousands of venomous coral and jellyfish, too. Venomous and poisonous are very different, of course.

How did you get into working with venom?
My background is in genetics. I was a molecular biologist at Pfizer, and at very large companies you often end up doing what they need you to do, rather than what you came there to do. So I started to work less on molecular biology and more on biosafety, and became involved in purchasing venoms for a project. The big problem was that there weren't any obvious suppliers and the ones that did exist did not conform to EU regulations. At the same time I have always been interested in exotic pets.

We first set up the company behind a pet shop and the first practical step was to apply the health and safety skills I had to develop safe methods of husbandry and venom collection.

What does an average day involve now?
We now have a pharmaceutical grade laboratory where we have more than 100 different species of venomous invertebrate – it's very different from traditional rodent facilities. I don't really have an average day, but at some point I'll typically supervise some of the venom extractions, or do it myself if it is a particularly tricky one or a new species. We've just received some soft coral, which is a new one for me.

What do you enjoy most about pharmacology?
Being able to deliver tools for difficult drug targets that I know challenge many of my pharma colleagues is very rewarding. Being a biologist is a way of life for me and the snake hobby was purely an enabler. The driving force for me is the pharmacology of how these molecules have evolved and can be turned into useful drugs.


The fer-de-lance viper's venom causes a catastrophic drop in blood pressure

Profession
Managing director, Venomtech
Qualifications
Genetics BSc, Aberystwyth
Interests
Venom biology, exotic pets, invertebrate physiology and anatomy, drug discovery

Pit viper venom provided the basis for the development of ACE-inhibitors

Aerobiology

The study of airborne biological particles

Clouds of pollen leaving the male cones of an umbrella pine, a source of hay fever

Aerobiology is the study of airborne biological particles and their movement and impact on human, animal and plant health.

Why is it important?

Allergens in airborne pollen or fungal spores are the cause of hay fever or allergic rhinitis in more than 20% of the UK population. Many fungal spores carried in the air are pathogens of UK crops or cause allergies in animals, so tracking these particles is also important to the agriculture industry.

What careers are available?

Aerobiology is a multidisciplinary field. Careers mostly involve sampling air quality and public health, immunology research, environmental protection or agriculture. Research and forecasting organisations around the world advise the general population and the medical and farming industries, and many commercial companies are developing allergen detectors or products to counter the symptoms of allergies.

Aerobiologists often work closely with medical doctors, plant pathologists, mycologists and meteorologists. Aerobiological observations are used in many other disciplines: palynology (the study of dust), ecology, botany, phenology, climatology, meteorology and forensics.

How do I get into a career involving aerobiology?

Many working in aerobiology will have specialised in microbiology. There are master's degrees available that focus on allergies and infections from universities such as Worcester and King's College London. Many biology undergraduate courses run modules specifically on allergens. Basic and advanced aerobiology courses are also organised by the International Association on Aerobiology (IAA).

Where can I find out more?

The IAA organises courses and annual meetings.
- https://sites.google.com/site/aerobiologyinternational

The National Pollen and Aerobiology Research Unit uses state of the art facilities to monitor airborne particles in the UK.
- pollenuk.worc.ac.uk

The IAA organises the Quadrennial Congress (International Congress on Aerobiology – ICA) which will be held in Sydney, Australia, in September next year.

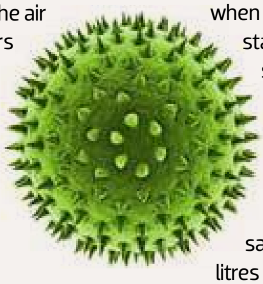
FIRST PERSON

Professor Roy Kennedy

What does your research involve?
We are best known for our pollen forecast, which we do in March, from the beginning of the season, through to October. We've been doing it for nearly 20 years. Pollen concentration is dependent on vegetation coverage and phenology – when grasses and flowers are opening and releasing their pollen – but also the weather, so it's a collaboration with the Met Office.

We also work closely with Worcester acute hospital and tweet our pollen forecasts to their respiratory doctors, many of whom are honorary members of the unit. If you know in advance you can start to take your medicine earlier and lessen the effects of the allergens.

What other applications are there for your aerobiology research?
Many fungal spores carried in the air are plant pathogens. So farmers can minimise their pesticide use if they are able to track when particular pathogens will pass over their crops and when they won't.



We have also found the amount of allergen within the pollen varies and research suggests it could be to do with climate change. We are working with physicians at Worcester Acute Hospital on using immunotherapy treatments for controlling allergies and there is even research looking at products to harden the lining of the nose so it is less sensitive. Don't forget, there's also the indoor aerobiology environment – house dust mites and pets, and the materials they give off, that many people are sensitive to.

Did you help to track the spread of ash dieback?
We were involved with reviewing the information on ash dieback and the techniques that could have been used to alleviate it. Many believe it only takes one or two spores to create an epidemic, but this is generally not the case. We are not just talking about detecting spores, but the likelihood of there being enough to establish an infection. Similarly, there are threshold levels of specific allergens required for sensitisation in humans.

How do you sample air for biological particles?
About 20 stations across the UK send us data. They are mostly other universities and hospitals, where the amount of pollen is measured on a daily basis. That is then sent to us and fed into our daily forecast. The two major allergens that cause hay fever come from birch tree pollen early in the season and grass pollen.

I think people would be surprised by what you find over a 24 hour period. Air samplers vary. The ones from the 1950s, when aerobiology really had just started, were the industry standard for a long time and particulates were basically impacted on a bit of sticky tape and then looked at under a microscope.

Now we have high volume samplers that can sample 500 litres of air per minute and separate particulates into different sizes; or pregnancy test style kits that give you a colour reading in the presence of particular allergens – a lab on a stick. You can even get an app that calculates the concentration of certain airborne particles using an iPhone. You don't need a lab any more.

Where is aerobiology research heading?
For a long time aerobiology has concentrated on microscopic tests and we need to focus more on genetics and applying the science of genomics to airborne biological material. As well as whole cells, we want to look at which individual genes are present and causing allergy, and what's going on within populations of fungal pathogens and allergen producing pollens.

Profession
Director, National Pollen & Aerobiology Research Unit, University of Worcester

Qualifications
PhD in plant pathology, University of Sydney, Australia;
MSc in mycology, Queen's University Belfast;
BSc (Hons) in botany, Queen's University Belfast

Interests
Pollen and fungal spore-related allergies, infectious agents, fungal genomics and population studies

We tweet our pollen forecasts to doctors in Worcester

Agroecology

The study of farm ecosystems

The discipline helps find new approaches to sustainable farming

Agroecology is the study of farm ecosystems. Agroecologists use the principles of ecology to help design and manage sustainable agricultural systems. Because the field looks at entire ecosystems, land use and complex farming processes, agroecologists often have to consider the interaction of economic, social, cultural and political factors in their work.

Why is it important?

Some projections predict that by 2050 the world will have to double food production to ensure the population has enough affordable food. New approaches are required to provide for the agricultural needs of present and future generations without depleting natural resources or degrading the environment. Agroecology aims to sustain or increase the productivity of agricultural systems while minimising the negative environmental and socioeconomic impact of modern farming methods.

What careers are available?

Agroecologists work in a variety of careers, including crop and farm management, the agribusiness and agri-tech sectors, and for various environmental, farming or regulatory agencies. Academic research posts are wide ranging, and cover many things, including the optimisation of yields of various food or biofuel crops; the reduction of the effect of farming on climate change; the population dynamics of crop pests and other farm flora and fauna; the study of pollinators in the farmed environment; soil microbiology; and, most hotly contested, the genetic modification of organisms used in agriculture.

How do I get into agroecology?

Most agroecologists will have studied a biology or ecology degree, many going on to specialise in crop, food or plant sciences, zoology or entomology. Rothamsted and Coventry University (see right) are the UK's main centres for agroecology research in the UK. Many charities and American colleges run agroecology courses to help improve conditions in farming communities around the world.

Where can I find out more?

The British Ecological Society offers research grants, resources, publications and membership for aspiring ecologists.
● www.britishecologicalsociety.org
Rothamsted Research is the longest running agricultural research facility in the world. It has an archive of resources for students and scientists, and runs a number of public meetings and national sampling projects every year.
● www.rothamsted.ac.uk
The Centre for Agroecology and Food Security is a joint initiative between Coventry University and Garden Organic, an organic growing charity.
● www.coventry.ac.uk/agroecology-and-food-security

FIRST PERSON

Hayley Jones

What does your research involve?
I'm looking at the dispersal ability of different species of macro moths (mainly moths with a wingspan of more than 1cm). We don't understand much about their mobility so I'm trying to quantify the dispersal ability to see if it is related to their current population changes – there are a lot of species declining in numbers and a few that are increasing.

How do you measure that?
I'm measuring it using a tethered flight mill system – we attach the moths to an arm which turns round on an axis. The moths fly round in a circle and a computer records how many revolutions they make so I can gather information about their speed, the distance they've flown and how much time they spend travelling. I'm using this data to get an idea of how good they'd be at dispersing in the wild.

So they'll happily fly round and round even though they're not going anywhere?
Yes. Moths don't really require much stimulus for them to fly – whereas people tried to use flight mills with bees and found you need to give them all sorts of visual stimulus to make them fly. It's quite variable, but some fly for the whole night.

What does your research suggest is going on?
The wider study from the Rothamsted survey that found many species are declining attributed this to different things, such as climate change and habitat loss. The theory is that the moths best equipped for flying may be the ones that can move north as the climate changes, or find new habitat if theirs is destroyed. The moths with the poorest mobility are therefore also the ones in decline.

How does this relate to the agriculture industry?
We are concerned about the moths that are in decline, but at the other end of the scale those that are very strong dispersers could become pests as the climate warms. We already have some species in the UK that are pests of garden and house plants, but we need to keep an eye on them as they could become crop pests. We could also potentially have dispersal from the continent causing problems in the UK.

What does an average day involve?
I start by emptying my moth trap in the morning. I select certain species that I'm focusing on, then I take them to the lab where they are chilled for a couple of hours so they are calm when they are attached to the pin. Then I feed them, connect them to the flight mill and leave them overnight. When I come in the next day, I take those moths off the flight mill and repeat the process.

How did you get into this line of research?
When I was at university, I was at a naturalist and bird watchers' society and we had a lecturer who was our unofficial patron. He'd run a moth trap every night for the past 30 years and he used to invite us to see him empty it. So I'd encountered moths but didn't think I'd want to study them as a career. But when I was looking at PhD projects, this one leapt out at me, and I thought not many people study moths, and that makes it more interesting.

It's a very satisfying thing to work on – the information could be used to focus conservation priorities on certain species of moths. It's a group that is very important and an indicator species.

Large yellow underwing moth (noctua pronuba)

Profession
PhD student
Qualifications
BSc (Hons) in biology, University of York
Research Interests
Ecology, agroecology, entomology, dispersal, population dynamics, conservation

Moths don't require much stimulus for them to fly

Cryobiology

The study of how low temperatures affect organisms, systems and materials

Low temperatures have been used to control food spoilage for centuries

Cryobiology is the study of how low temperatures affect organisms, biological systems, or biological materials. Research uses temperatures ranging from slightly lower than normal (hypothermic) to cryogenic (–150°C and lower).

Why is cryobiology important?
Low temperatures have been used in medicine and to prevent food spoilage since ancient times. Nowadays cryopreservation (freezing) is used in fertility treatment, for the transport of human organs, and the long term storage of biological specimens, either for future study or simply as a record of biodiversity.

Certain bacteria can survive thousands of years in extremely cold temperatures, while many plants and animals have interesting adaptations to prevent their tissues freezing.

Cryogenics is a field outside mainstream cryobiology, which involves freezing human bodies or body parts, such as the head, in the hope of future revival. This remains a distant prospect.

What careers are available?
Cryobiologists work in a range of industries and research areas. There are many industrial and medicinal applications of cryopreservation (see interview opposite) and low temperatures are used in a range of direct medical treatments, from minimally invasive 'cryosurgery' to simply freezing warts off. Careers are available developing the tools and technology of these processes as well as in the research labs and industries that use them.

The study of cold-adapted organisms and the effect of low temperatures on biological material is also a huge area for research, with many applications in industries such as agriculture, for example protecting plants from frost. Cryo-electron microscopy is a special research tool that allows scientists to study biological materials without fixing them or staining them.

Where can I find out more?
The Society for Cryobiology and the Society for Low Temperature Biology have promoted the work of cryobiologists since 1964. They both host an annual international meeting and the Society for Cryobiology publishes the journal *Cryobiology*. See their websites for information on cryobiology research, jobs, endorsed cryobiology related courses and meetings.

- www.societyforcryobiology.org
- www.sltb.info

FIRST PERSON

Dr Serean Adams

What does your research involve?
I develop cryopreservation techniques for preserving the sperm, eggs and larvae of the commercially important shellfish species we have here in New Zealand – green shell mussels, pacific and flat oysters, abalone and geoducks (*Panopea generosa*), a large edible clam. I'm developing the freezing techniques and making them robust enough to apply in selective breeding.

How does cryopreservation help selective breeding?
Being able to store the embryos or sperm gives breeders more control – you can make crosses on demand between particular individuals and it provides a bank or library of your most valuable individuals that you can go back to, which is important if breeding objectives change. It also means you can create a reference family you can use to compare across generations, instead of using a bunch of wild families as a benchmark.

Mostly the industry is looking to breed shellfish with a high meat to shell ratio, but also it's about making really nice looking oysters. Oyster herpes had a huge impact on the industry recently so a lot of their focus is on developing disease resistant lines.

Has it put you off seafood?
I don't like oysters! I've tried geoduck sashimi, which was really nice. They have this long sort of neck called a siphon and you slice it up and eat it raw.

How do you freeze the shellfish embryos and sperm?
We use chemicals called cryoprotectants to protect the cells while they are cooled. Antifreeze (ethylene glycol) is used as it lowers the temperature at which the water in the cell freezes. Some work outside the cell or stabilise the membrane. These chemicals are often toxic to the cell and their effects vary so we play around with different amounts for each species.

It is also important to control the rate of cooling and warming. When ice forms in the extracellular space, it draws out water from the extracellular solution. Water is drawn out of the cell too. If we cool the cells sufficiently slowly to an intermediate sub-zero temperature (about -30 to -40) then almost all of the water moves out of the cell and eventually when we plunge the cells into liquid nitrogen, the cytoplasm of the cell is sufficiently concentrated that it vitrifies (forms a glassy state). If there is still lots of water inside the cell, ice will form intracellularly and that kills the cell. Equally if we cool really slowly we expose the cell to high solute concentrations and can damage the cell that way.

The term 'cryobiology' conjures up images of a classic science lab with lots of dry ice fog and bubbling liquid nitrogen. Is your lab like that?
Ha ha, yes. Half of what I do is like witchcraft, half of it is science. There is a lot of mixing together various cryoprotectants and we use dry ice, liquid nitrogen and specially controlled freezers. We also make little rafts out of polystyrene that float the specimens just above the liquid nitrogen. The thicker the raft, the slower the rate of cooling.

What do you like about cryobiology?
It is such an interdisciplinary field. There are so many interesting people, in such a diverse array of fields, applying it in so many ways.

Samples are frozen with liquid nitrogen

Profession
Cryobiology and marine biotechnology scientist, Cawthron Institute, New Zealand

Qualifications
PhD (marine science), University of Otago

Interests
Shellfish aquaculture, cryobiology, reproduction and developmental biology in aquatic species, marine biotechnology, conservation biology, ecotoxicology

Being able to store the embryos or sperm gives breeders more control

Photobiology

The study of the interaction of light with living organisms and biological systems

Bioluminescent algae *Noctiluca scintillans* on the Maldive islands

Photobiology studies the interaction of light with living organisms and biological systems. Photobiological responses are the result of chemical and or physical changes induced in biological systems by any non-ionising radiation.

Why is it important?

Most life on Earth is sustained by the harnessing of the Sun's energy by photosynthetic organisms. Photobiologists not only study the way organisms react to light, but use light to find out more about the properties of living tissue or biological molecules.

Light can be used in various therapies and treatments for disease and is used widely in the sterilisation and imaging industries. Certain fascinating organisms produce light themselves (bioluminescence) and scientists increasingly use their luminous pigments as a tool in biological research. It is thought engineered bioluminescence could one day replace conventional electric lighting.

What areas can photobiologists work in?

The study of how living tissue interacts with light is important to a huge range of research areas and industries. Much research is focused on the causes and treatment of skin cancers and other dermatological disease, for example, while climate change studies depend on research into how plants and aquatic ecosystems use and reflect the Sun's energy. Photosensory biology is another large research field, covering everything from vision to circadian rhythms and phototropism (growth towards or away from light).

In terms of using light, bioluminescence imaging involves splicing segments of DNA that codes for luminous proteins into cells or organisms to study biological processes non-invasively. It is now used widely in genetics and clinical research. In industry spectroscopy, sterilisation and sampling products are all reliant on scientists with an understanding of light.

How do I pursue a career in photobiology?

Educational routes depend on the particular aspect of photobiology that is of interest. For example, someone working in an environmental setting or photosynthesis research may have studied biology or biochemistry before going on to specialise in plant photobiology. Someone working in laser therapy, however, may have studied medicine or physiology and then conducted research in the dermatology unit of a hospital.

The field is so diverse that there are very few undergraduate courses in the subject. The European Society for Photobiology offers a short annual course covering the main aspects of the field (photomedicine, photosynthesis, photosensory biology, fluorescence diagnosis) for MSc or PhD students and occasionally universities offer PhD level courses (such as the University of Oslo).

Where can I find out more?

The European Society for Photobiology and The American Society for Photobiology offer education, training, events and papers of interest for members.

- www.photobiology.eu
- www.photobiology.org

FIRST PERSON

Dr Joanna Turner

What does your research involve?
My research involves monitoring UV radiation – specifically the reflective properties of man-made structures. It's important to help understand the impact it has on people – Australia has such high UV levels as it is, and the highest rate of skin cancer in the world. People working in the construction industry are especially exposed and often working alongside highly reflective structures.

My preliminary studies suggest if your face is facing, say, galvanised metal, UV levels may increase by up to 50%. Even painted and less reflective surfaces have an impact over time. I'm trying to develop ratings for different material types.

What does an average day involve? Presumably you spend a lot of time outdoors.
Yes, when I'm doing research much of it is outside. When I go in to talk to schools I tell them that my uniform isn't a lab coat and goggles, it's a hat, sunglasses and sunscreen! But we also have machinery at the university that generates UV light, so we work in the lab, too.

Do photobiologists tend to work in hot sunny areas?
I'm not sure about that – the birthplace of the field was in England I think. There are people from all round the world working here, but also lots of people from South America, which has similar problems with ozone depletion to Australia.

What other areas of biology could benefit from your research?
I'd love to find out more about the reflective properties of butterflies, and bees are sensitive to UV light – flowers reflect UV light to attract them – so it would be interesting to use research on UV reflection and how it affects their vision.

How did you get into photobiology?
I think of myself primarily as a photophysicist who is interested in how photons affect biological systems. I mostly use chemical sensors so I've done some chemistry too, and quite an array of people join us here – lots of them from the biology arena. I did physics at university and postgraduate research for a UV expert, so that's how I got into that side of things.

What else interests you in the field?
I would love to get into the technology of detecting UV. Reflective UV photography can give us a lot of information about UV light. I am also involved with getting young people interested in photobiology and science in general.

Children need more opportunities to be excited by science at school, because the younger generation are the future of science. I currently do a fun experiment with paper that changes colour under UV radiation, which children of any age can do.

Sun rising in Queensland, Australia

Profession
Associate lecturer at the University of Southern Queensland; council member of the American Society of Photobiology
Qualifications
PhD, physics – University of Southern Queensland
Interests
Ultraviolet radiation measurement; ultraviolet radiation reflection from man-made structures; science education research

My uniform is a hat, sunglasses and sunscreen!

Sustainable agriculture

Uses the principles of ecology to make farming efficient and environmentally friendly

Researchers and advisers are needed in many areas, from crop science to environmental policy

Sustainable agriculture uses the principles of ecology to make farming as efficient as possible with minimal or even positive environmental impact. It is the production of food or other plant or animal products using farming techniques that protect the environment, public health, human communities and animal welfare.

Why is it important?
It is predicted that the world will need to double food production by 2020 to sustain its growing population. At the same time, using more land to raise animals or grow crops only exacerbates global problems such as deforestation and climate change. Sustainable agriculture aims to balance the needs of society with the protection of the environment, while also ensuring that producers make fair profits.

Who is involved?
Many people contribute to the ideas of sustainable agriculture; that we must meet the needs of the present without compromising the ability of future generations to meet theirs. The science of sustainable agriculture is just one aspect of a complex issue involving politics, socio-economics, trade and the environment.

The drive to encourage populations to produce and trade products more sustainably goes beyond science and technology. It often involves people working together across government, farming, the civil service, the retail sector, think tanks, charities and even activist groups.

What careers are available?
Government departments and agencies require scientists to help research and advise on specific aspects of sustainable farming, including water, soil, energy, air, crops, domestic animals, wildlife and ecosystems. As with all green issues, sustainable agriculture involves complex and overlapping government policies concerning agriculture, environment, energy, business, conservation and transport. As a result, positions can be found in all areas of policy-making, from local authorities to international organisations such as the EU Commission and the UN. Likewise, many environmental charities and green businesses employ consultants with knowledge of sustainable agriculture to ensure the products we buy do not damage the environment and reward producers fairly.

How do I get into this area?
Agriculture degrees are available from UK universities, but there are various other routes into this field via related degrees such as crop, food or plant sciences, and ecology. Coventry University and Rothamsted Research are major centres for agricultural research in the UK, and many charities and US colleges run agroecology courses that aim to help improve conditions in farming communities around the world.

Where can I find out more?
The UK Plant Science Federation represents agricultural scientists and plant science policy-makers in the UK.
● www.plantsci.org.uk
In the US, there are local sustainable farming associations, while Sustainable Agriculture Research and Organisation promotes sustainable agricultural innovation nationally.
● www.sare.org

FIRST PERSON

Professor Les Firbank CBiol FSB

What do you do?
I'm working for the Sustainable Intensification Platform, a major national project to pull together the community to increase productivity and resilience without damaging the environment and hopefully even making it better. It's very practical, using studies from individual farmers and looking at how their stories fit in with the global narrative.

My academic expertise is in how to monitor interactions between biodiversity and agriculture. My skills are really in experimental design – that is, seeing what skills are required to solve a particular problem, and building a team from various disciplines, such as social scientists, soil scientists, engineers and even legal professionals. I previously led the Centre for Ecology and Hydrology's Farm Scale Evaluations of GM Crops, the largest agro-ecological experiment of its kind.

I believe you won a gold medal at the 2012 Chelsea Flower Show.
Yes, that was fun. We were invited to put an entry into the show out of the blue. None of us were that fond of gardening, but the idea of a garden teaching people about ecosystem services in an urban setting was hard to resist. We found that Leeds City Council's head gardener wasn't submitting an entry that year so we got him on board and he understood the concept very quickly. We got a lot into a very small indoor space – vegetable crops, wetland, composting, pollinators, rainfall capture, a permeable path – lots of little things. We also didn't know you aren't allowed to encourage people to walk around the garden like we did.

Is a big part of sustainable agriculture about spreading the message about what works?
Yes, lots of people picked up practical things from our garden that they could take home and try. That's how a lot of these messages need to come across. All farmers want to be more efficient, environmentally sound and profitable – you just need to help them find ways to do it. Trying to dictate a new way of working doesn't work and would actually be quite arrogant of the research community.

How did you come to be a professor of sustainable agriculture?
I grew up on a farm and went to Imperial College London to study biochemistry. I became hooked on the ecology lectures and all the wonderful environments you could visit as part of that. Each step of my career flowed quite naturally after that.

What sort of people are attracted to sustainable agriculture?
It's a very sociable field. It isn't like lab groups where people work individually or in very small teams: it's a discipline that you can't do by yourself, as ideas change quickly and come from all over the place. We have a uni farm that's being used by us, our soil scientists and scientists from York and Manchester. It makes the science better and it's more fun. Sustainable agriculture is less of a discipline and more of a meeting ground, I suppose.

Where is the discipline heading and what areas will be exciting in the future?
The thing that excites me most is that it's in demand. It's increasingly accepted that we need more production and that has to be done more sustainably. I think growth areas will be sensor technology, the use of big data and engineering, and there'll be much greater engagement with industry.

Farmers need help to be environmentally sound

Profession
Professor of sustainable agriculture, University of Leeds
Qualifications
BSc in zoology; PhD in plant population dynamics
Interests
Sustainable land use, sustainable intensification

It's a discipline you can't do by yourself, as ideas change quickly and come from all over the place

Bioinformatics

The application of information technology to biological problems

Bioinformatics is dependent on large amounts of genetic data

Bioinformatics is the application of information technology to biological problems, most commonly the analysis of DNA, RNA and protein sequences or structures. It relies heavily on the use of IT, mathematics, and statistics to capture, store, and analyse complex biological information.

Why is bioinformatics important?
Recent advances in molecular biology and genomic technologies have led to an explosion in the amount of biological information generated by biologists. This has led to a huge demand for specialist tools to store, organise, view, index and analyse such data.

Bioinformatics can generate new understanding in genetic interactions, metabolic pathways and drug development. It is crucial to the development of software and technology that assists biologists' research.

Some believe that to work in any biology related field in the future, biologists will need certain competencies in bioinformatics.

What careers are available?
The IT, pharmaceutical and biotechnology industries are all in need of bioinformatics graduates to help develop products like research software or drugs. There is a high demand in the 'omics' research fields (such as genomics, proteomics and glycomics) for competent analysts and computing solutions to process the large quantities of data produced by researchers.

Big employers in the UK include the major pharma companies, the European Bioinformatics Institute, the MRC's Human Genome Mapping Project Resource Centre, and the Wellcome Trust Centre for Human Genetics. Smaller companies are using bioinformatics too, including those involved in agricultural applications, industrial organisms and personal care products.

There is generally thought to be a shortage of expert statisticians working in many areas of biology and bioinformatics.

How do I get into a career involving bioinformatics?
Universities tend to run postgraduate courses in bioinformatics for those with a computer science or bioscience background. Some, such as Imperial, Cranfield or Manchester universities, offer master's courses in bioinformatics or the related computational biology and systems biology. There are many shorter practical training courses to teach scientists how to use specific software tools.

Where can I find out more?
You can find information and announcements on bioinformatics research, industry and education at the Bioinformatics Organization website.

- www.bioinformatics.org

There is also a network for those working in bioinformatics research or industry.

- www.embnet.org

FIRST PERSON

Professor David Jones

How did you get into bioinformatics?
The word bioinformatics didn't exist when I was a PhD student in 1989. This sort of work was being done of course, but the word didn't appear until the early 1990s.

My first degree was in physics, and I wanted a career in science, but was also really interested in computing. I saw a programme on the discovery of the DNA helix and it occurred to me that biological problems could be approached theoretically, with maths, and computationally. I took biophysics modules in my third year and did my master's and PhD in biochemistry. I became fixated with protein folding and that was it really. I thought, "I can do everything here" – computing, physics and answering questions in biology.

What are you working on at the moment?
Predicting and simulating the way proteins fold, based on their amino acid sequence, is the area I spend most time on – I think if you do a PhD its central question never leaves you unless someone solves it completely. But my lab is looking at many other interesting things like protein and gene function. What does this protein or gene actually do? What is the definition of the function of a gene?

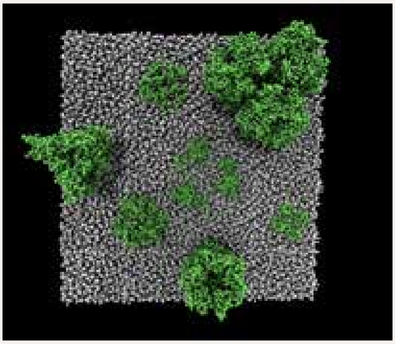
What is the bread and butter equipment of a bioinformatician?
In the early days you needed special graphics systems that cost a bomb. But most of what we do now can be done on a standard PC. Some calculations require high-throughput computers, which we have here at UCL. But again, once you get the data back, much of the analysis can be done on a standard machine.

What sort of person makes a good researcher in bioinformatics?
In my group the best bioinformaticians come from a variety of backgrounds. There are people from biology and chemistry backgrounds who have picked up the relevant skills, as well as physicists and computer scientists. I have a joint appointment across the computer science and biology departments, so I get to interact with colleagues in both departments. I can't emphasise how important good statisticians are: it's the difference between getting numbers and results.

What would you say to biologists who are daunted by the complex mathematics?
People overestimate how difficult it is to tackle these problems without a maths or physics degree. It's about getting the right data and using the right tools. Underlying the complicated equations and programs are very simple ideas.

What areas excite you in terms of future applications?
A lot of funding is being directed at synthetic biology. If I could pick another problem to work on it would be the design of new proteins that are not found in nature and have novel functions. You could put proteins together that could never work in a cell or from different organisms, modifying biology for endless industrial or medicinal uses; you could create a new biological machine.

The iGEM competition (www.igem.org) – where undergraduate teams get together to come up with novel synthetic biology projects like this – shows it's already happening. If I'd seen this when I was an undergraduate I'd have given all the money I had to get involved.



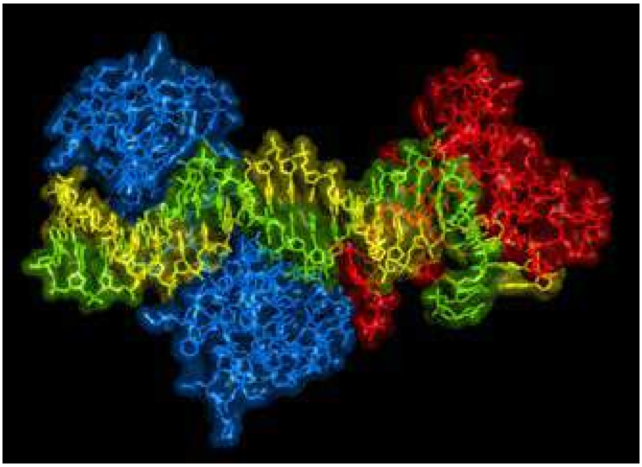
Example of 3D protein structures from Professor Jones' lab at UCL

Profession
Head of the Bioinformatics Group at University College London and director of the Bloomsbury Centre for Bioinformatics
Qualifications
PhD biochemistry from University College London; MSc biochemistry from King's College London; BSc physics, Imperial College
Interests
Protein structure prediction and analysis, simulations of protein folding

Underlying complicated equations are very simple ideas

Epigenetics

The study of changes in gene activity not caused by changes in the DNA sequence



Transcription factors bind to specific sections of DNA, making genes more or less active in different cells

Epigenetics is the study of any changes in gene activity not caused by changes in the DNA sequence.

Why is it important?

Epigenetics explains almost any change in DNA function that is not caused by a mutation. The 'epigenome' at its simplest is the cellular machinery that switches on or off certain genes, allowing stem cells to differentiate into all the cell types required to make a human being.

Adding methyl groups to DNA (DNA methylation) or modifying histones (the proteins that package DNA) are ways of changing how genes are expressed without altering the underlying DNA sequence. Although exquisitely complex, with one epigenetic change often causing a cascade of further epigenetic changes, researchers can now remodel the epigenome of organisms using these techniques and study the effects.

DNA was once thought to be an inflexible code that set out our phenotype from birth, but it is now known that the epigenome, operating above the level of the genome, can change how DNA is expressed throughout our lives, depending on all sorts of factors, such as our environment. As a result, epigenetics is of huge relevance to the study of both development and disease, especially cancer.

What careers are available?

Its huge potential as a medical treatment means that most epigenetics work is focused on biomedical research. Cancer epigenetics is probably the largest field, with hundreds of institutes worldwide looking to identify biomarkers of the disease and epigenetic drugs to treat it.

Huge sequencing programmes, such as the National Institutes of Health's 10 year Roadmap Epigenomics Project in the USA, are surveying epigenetic variation on a genome-wide scale, while smaller laboratories use this data to answer more specific questions about the mechanisms of disease.

There is a high demand for biologists with computational, bioinformatical or mathematical expertise to help process the vast amounts of data produced by epigenetic research. Medical doctors are increasingly moving into epigenetics research fields related to their disease speciality.

Where can I find out more?

The Epigenetics Society is an international scientific organisation open to all those interested in the field.

- es.landesbioscience.com

The EU-wide Epigenesys network provides epigenetics news, research and events for scientists and interested members of the public.

- www.epigenesys.eu

The Human Epigenome Project aims to map all the epigenetic variation found on the entire human genome and its website contains most of the data and publications from the project so far, as well as details of the contributing organisations.

- www.epigenome.org

Johns Hopkins University is a world leader in epigenetics research, topping the list of citations for institutions in the field. In the UK, the Babraham Institute, Institute of Cancer Research and Wellcome Trust Sanger Institute join the many universities actively researching in this area.

- www.jhu.edu

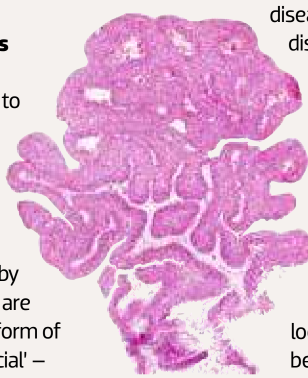
FIRST PERSON

Professor Wolf Reik

What does epigenetically 'reprogramming' cells involve?
We work mostly with lab mice and all the cell types you can derive from them – like stem cells, liver cells etc. But the process actually happens *in vivo*, which is how we first came upon it. In normal development, say in germ cells or embryogenesis, there is an enormous removal of epigenetic information in many areas of the genome. In adults, different cells have a different epigenome which, for example, makes liver cells act like liver cells and brain cells act like brain cells. When you form an embryo you need to 'wipe the slate clean', meaning the cells afterwards have the potential to grow into any cell type needed.

What about the evidence that some epigenetic information is passed on to the next generation?
Large scale reprogramming happens and most epigenetic information is lost in the next generation, but it is possible that a small part of it survives. An interesting recent example is the study of mice and smell (Dias, B.G, *Nature Neuroscience*, 2013) where something that happened in the previous generation appears to have been passed on through inherited epigenetic information. It is controversial, but an interesting possibility.

What other research does the lab do?
A lot of people are starting to look at caste division in insects – at how the difference between workers and queens, who may be genetically identical, can be explained by epigenetic differences. We are particularly interested in a form of wasp that is 'primitively social' – that is, the caste is not fixed, is determined quite late, and you can't distinguish the queen from the workers just by looking at them. A new queen can emerge from the workers if you remove the queen. If castes are epigenetically determined, maybe you can reprogramme social behaviours by changing the epigenome.



Cancers – such as bladder tumours – are being studied epigenetically

What are some of the aims of this work?
Our work has led to a better way of making stem cells, and there are already epigenetic drugs that remodel the entire epigenome in cancer patients. I think in future we will have a more refined approach where we can manipulate specific parts of the genome epigenetically at will, when you see something has gone wrong with it.

How did you get into this research?
I'm a medical doctor, trained in Germany. I did a PhD with one of the pioneers in this area, Rudolf Jaenisch. I became fascinated by thinking about cell differentiation in an epigenetic way, before the field was even called epigenetics. I established my own lab in Cambridge, then started the epigenetics programme at Babraham. Epigenetics is really quite a large industry now, and it's been fantastic to see the subject grow.

What does the future hold for epigenetics?
There are very many big questions out there, quite basic biochemical ones, but also ones surrounding common human diseases – diabetes, cancer, heart disease. How much is explained by genetics and the environment, and how does the epigenetic dark matter contribute in these diseases?

Is epigenetics about answering the 'nature vs. nurture' debate?
That's exactly how you can look at it, as an integrator between the genome and the environment. It's a good mental picture to use, but it's important to know how much in that picture we don't know yet.

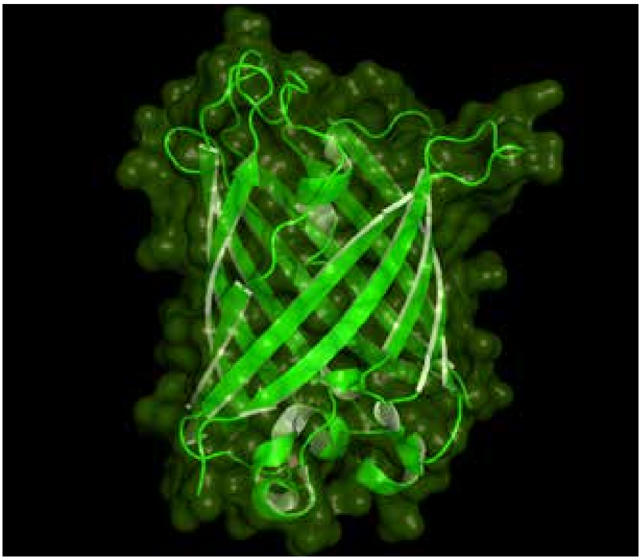
Profession
Head of the epigenetics programme at the Babraham Institute in Cambridge

Interests
'Epigenetic reprogramming', where epigenetic instructions are removed from a cell to revert it to an undifferentiated, or stem, cell

What does all this 'dark matter' in the genome do in these diseases?

Proteomics

The large-scale study of proteins



A rendering of a green fluorescent protein used as a biosensor

Proteomics is the large-scale study of proteins. The term was coined in the 1990s to make an analogy with genomics, the study of genomes. The entire set of proteins that are made by an organism or cell type is known as its 'proteome' and proteomics attempts to catalogue and understand these enormously complex sets of molecules.

The field combines skills and techniques from chemistry – such as mass spectrometry and electrophoresis – with specialised mathematical modelling and computing known as bioinformatics.

Why is proteomics important?

Proteins are essential components of life, performing a vast array of functions and forming many of the structures found in living tissue. Now that the genomes of many organisms have been mapped, to truly understand biological systems, we need to understand the role of all the proteins produced in each cell. Genes are merely the 'recipe' for creating a bewildering array of functional proteins, and so proteomics arguably holds even more promise than huge genomics programmes such as the Human Genome Project.

How come I've never heard of it?

Studying proteins has always been an essential part of many fields, such as cell biology, molecular biology, developmental biology, medicine and biochemistry, but the large-scale study of proteins was not possible until the arrival of high-throughput screening and computing technologies. Proteomics labs tend to develop specialist tools to support researchers in other fields who work with these complicated molecules.

What careers are available?

Clinical proteomics is a growing field that studies the protein 'biomarkers' that help predict or diagnose disease. Many people with expertise in proteomics are employed in the healthcare and pharmaceutical industries to identify and assess these biomarkers to help develop diagnostics and treatments. Candidates need a good understanding of protein purification and analysis, requiring a PhD in biochemistry or a related field of biology, as well as industrial experience.

Biotech companies and university facilities provide specialist protein analysis services to other researchers or labs. Any proteomics research also requires experts in maths, computing and database design to process the data generated by protein analysis.

Where can I find out more?

Large projects such as the Protein Data Bank and UniProt are comprehensive and free resources containing information on the structure and function of hundreds of thousands of proteins and nucleic acids.

- www.wwpdb.org
- www.uniprot.or

The British Society for Proteome Research is a small charity that lists proteomics events and courses, while the British Mass Spectrometry Society has a protein analysis special interest group and forums on the topic. There are many other similar societies around the world.

- www.bspr.org
- www.bmss.org.uk

FIRST PERSON

Dr Bill Mullen

What do you and your research group do?
We work closely with clinicians to try to identify biomarkers of disease and find ones that are more specific and sensitive than existing ones. A lot of the work focuses on cardiovascular disease and obesity, and the resulting chronic kidney diseases.

How do you create an accurate 'fingerprint' of a disease?
We compare the proteome of people with these diseases and people presenting with similar symptoms. Comparing patients with healthy people is not particularly useful, as the proteins present are so different.

Lots of your analyses are of the proteins and peptides in urine. Why?
Everyone in this field started by looking at blood, but it was too complex. The concentration range of proteins is so large no machine could cope; it is like having a ruler that can measure both a human hair and Mount Everest at the same time. Also blood is changing, even after collection. Urine has a lower concentration range and there is no protease activity, so it doesn't change after sample collection.
What does your average day involve?

It's very much lab-based, but we have clinicians working within the institute and in the hospital next door. We are running mass spectrometers pretty much all the time.

Could you do what you do without today's cutting edge equipment?
No. Comparing 100 samples versus another 100 using the old analysis tools like 2D gels would be a lifetime's work. If it wasn't for the quantum leap we've seen in mass spectrometry, we wouldn't have proteomics.

How did you get into proteomics?
I started my own company designing machines to help measure metabolites. I started looking at proteomics for biomarkers of health in nutrition. At present there is no way of measuring improvements in cardiovascular health from eating more fruit and vegetables.

Do you think anyone thinking of a career in proteomics should have a passion for tools such as mass spectrometry then?
Yes, I've always worked with it and that is the field, basically. If you're going to get into science, it must be your hobby as well as your work. I'm still tweaking my machines and working on a new interface between devices that has taken us beyond what other analysis can do.

Aside from the kit, what do you like about proteomics?
The proteome is just such a massive area still to explore. Unravelling organisms' genomes was just the beginning. It's like that saying – every time you learn something, you find out two more things you don't understand.

What excites you about the future?
We currently pick up 'fingerprints' of disease by cataloguing the mass and migration of peptides present, but we don't really know what they are or what they do. Once we understand why these proteins have changed, we start to connect our discipline with the actual physiology of the disease. In the future I think you'll be able to take a urine sample, screen it for diseases and come up with a health report with recommended treatment options.

Profession
Director of biomarker research, Institute of Cardiovascular & Medical Sciences, University of Glasgow
Qualifications
MSc on phenolics in raspberries, PhD on flavonol metabolites, both from University of Glasgow
Interests
Mass spectrometry, proteomic and metabolite analysis, health and nutrition

The proteome is a massive area still to explore

Synthetic biology

The engineering of biological systems to create products or devices

Novel DNA sequences can be synthesised and inserted into the genome of existing organisms

Synthetic biology is the engineering of biological systems to create useful products or devices. It has the potential to create new life forms with extraordinary properties that exist purely to meet human needs.

Why is it important?

Synthetic biology is a fast-growing subdiscipline of the life sciences. In 2014 the Government identified it as one of the eight great technologies of the future and committed £40m to developing three synthetic biology research centres in the UK.

As well as splicing in genes from other organisms, novel sections of DNA can now be synthesised cheaply from scratch and inserted into organisms, creating experimental cells with new functions and features not seen before in nature. Synthetic biologists choose a 'chassis' organism and add features such as genes, the promoters that activate them and the systems they drive.

There are many parallels with open source software programmers, but rather than sharing code, scientists share DNA sequences that code for a certain feature. Open registries of synthetic biology 'parts' have helped drive rapid innovation.

How do I get into it?

There are numerous synthetic biology initiatives, networks and research centres. A huge amount of funding is available for projects with a synthetic biology slant and a range of competitions, such as iGEM, encourage innovative synthetic biology projects from teams in schools, universities and industry.

Thanks to cheap and commercially available toolkits, synthetic biology is also popular with the growing number of hobbyists known as 'biohackers' who use borrowed, homemade or unwanted lab equipment to conduct their experiments.

Courses in synthetic biology tend to be at postgraduate level, most as one-year master's degrees. Imperial College London offers a synthetic biology final year option as part of undergraduate degrees in biology, biochemistry or bioengineering, and some US universities such as Berkeley allow a synthetic biology specialisation during certain bioscience degrees.

What careers are available?

The field offers many opportunities for early career scientists. Practical applications of the technology include the production of biofuels, vaccines and antibodies, industrial enzymes and chemicals, and biomaterials and agriculture, with placements in industry to reflect these areas. However, the majority of careers remain in academic research.

Where can I find out more?

iGEM holds a global competition for schools and universities.

- www.iGEM.org

The BioBricks Foundation runs an annual international synthetic biology conference and provides resources for researchers.

- www.biobricks.org

Research Councils UK's Roadmap sets out a vision for synthetic biology in the UK.

- www.rcuk.ac.uk/publications/reports/syntheticbiologyroadmap

The Biotechnology and Biological Sciences Research Council and the Engineering and Physical Sciences Research Council fund research and have resources on their websites.

- www.bbsrc.ac.uk
- www.epsrc.ac.uk

FIRST PERSON

Dr Jim Haseloff

What do you do in your research lab?
There are two branches of our work. The first uses the Marchantia plant as a base organism for developing new plants. Our other work is looking at the way bacterial cells grow and interact – it sounds odd for a plant science lab, but bacterial cells offer the easiest access to cells' genomes and what happens as they grow.

How does your work with bacteria inform your work to develop new crops?
The genetic difference between the crop maize and its wild ancestor teosinte is minimal – the fact that maize is a useful crop is due to the way morphogenesis [the shape and relative size of parts of an organism] is controlled. If you can understand the changes that have been made over time to create maize from teosinte, you can potentially create very different versions of existing plants.

If you are trying to engineer morphogenesis in plants, it is the physical interactions between the cells that determine the eventual shape. You can't think about the shape of a group of cells without understanding the physics of how they divide and grow. When you scrape microbes on an agar plate, you'll often find they've formed perfect domes containing billions of cells within a few days. However, cells grow in one long string – it's a slight buckling of these cells as they divide that creates strange fractal patterns and an ordered structure. That is what I am looking at.

How do you define synthetic biology?
I think it's a lot like how before the industrial revolution if you wanted to engineer something, you had to make it all from scratch. And then in around the 1830s, you began to see standardisation of parts so you didn't have to think about making absolutely everything, like the nuts and bolts. I think biology is in that place now. Simple standards underpin the processes of, say, manipulating or reprogramming cells.

What other types of 'standard parts' do you use?
What's involved in making a living system? You have the chassis, then what do you want controlling that system – an entire genome, a control circuit made of DNA? Once you have that, you've got to use things to measure what's going on at the DNA, cellular, phenotype level. Then it's also often very important to have a computerised model of your system running alongside your experiment.

How did you get into synthetic biology? Presumably it didn't exist as a field when you began your career?
No, it didn't exist in name or intent, I guess. I came into the field in the 1970s when it was molecular biology. Even then, pre-internet, it was still about tweaking and refining techniques. Except then you would fly round the world to a lab and make handwritten notes that you'd then photocopy and they would be like gold dust.

Your OpenPlant project received £12m funding. What is it like to work there?
The funding is split into two halves: here in Cambridge and the John Innes centre in Norwich. In Cambridge, it's more about the fundamental science; in Norwich, the focus is on trait development. It's a really exciting collaboration, putting people who have been working in fundamental science into a context of trait development.

What sort of traits are you looking at?
Creating high value pharmaceuticals and vaccines from plants, improved nitrogen fixing, and altered photosynthetic capabilities.

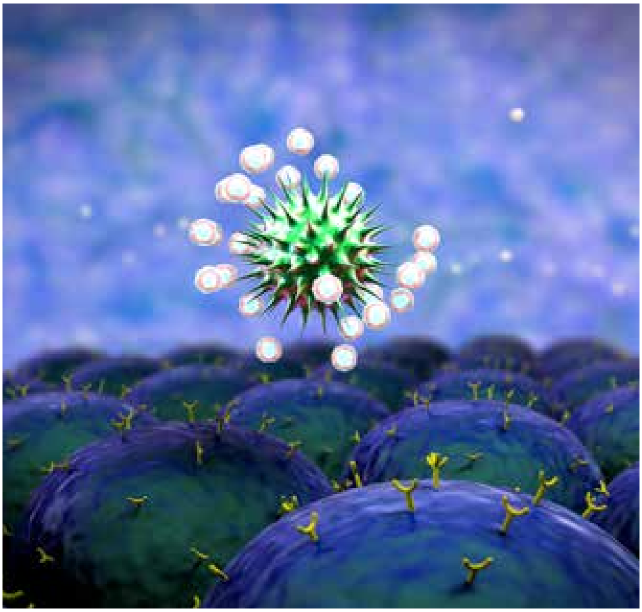
What other areas of synthetic biology are exciting for the future?
Metabolic engineering – creating molecules. The 1000 Molecule project creates biomaterials that can be used in different ways – for example, biological plastics. Light and creating bioluminescence is also something that really fascinates me.

Profession
Reader in synthetic biology at the University of Cambridge, head of the Haseloff Lab, Cambridge
Qualifications
PhD (biochemistry), University of Adelaide; Research Fellow, MRC Laboratory of Molecular Biology; Research Fellow, Harvard University
Interests
Plant development and morphogenesis, precise monitoring of cell behaviour, engineering of tissues in plants

Cells grow in a long string – it's a slight buckling of these cells as they divide that creates an ordered structure

Systems biology

The study and modelling of complex biological systems



Model of the human immune system attacking a virus

The aim of systems biology is to understand vastly complex biological systems in a way that allows us to model and predict how they will behave. It often uses mathematical and computer modelling to define the rules and principles that govern and regulate systems, which can range from microbial cells to organs or even entire ecosystems.

Why is it important?

Systems biology is helping our understanding of complexity itself, not just the principles that underlie complex systems. Systems biologists aim to develop a quantitative as well as a conceptual understanding of biological phenomena, which permits the prediction and accurate simulation of extremely complex processes such as the immune response, or epigenetic changes during disease. The ability to model and predict what happens to systems under certain conditions is already having a profound effect on how theories are tested.

What does systems biology involve?

In some ways systems biology is more easily defined by what it isn't: it does not take an element of a living system and try to control other variables in order to study it – typical of many bioscience experiments throughout the ages. Systems biology uses information and data from a wide range of sources to build as full a picture as possible, with computer modelling at its core to understand how everything in such an immensely complicated system is related.

Although a systems approach can be applied to many areas of the life sciences, it is often focused on combining genomic, proteomic and other molecular data to understand entire cells or groups of cells.

How do I get into it?

Systems biology is a relatively new field – the term only really entered the scientific lexicon around the year 2000, but there are around 15 universities with dedicated systems biology departments or research groups in the UK and hundreds across Europe and the world.

Many opportunities currently are rooted in academia and fundamental research at PhD and postdoc level. In the UK, there are a number of systems biology master's available, many of which focus on bioinformatics and computing. Undergraduate degrees in systems biology are less common but are available, especially in the US. Such courses often have a molecular biology focus and may be combined with a related subject such as bioinformatics (see page 46) or computational biology.

Systems biologists are also employed in hospitals, the pharmaceutical industry, biotechnology companies and cancer institutions, where analysis of huge amounts of experimental data is required.

Where can I find out more?

The International Society for Systems Biology and the International Society for Computational Biology both provide information on systems biology careers, research and conferences.

- www.issb.org
- www.iscb.org

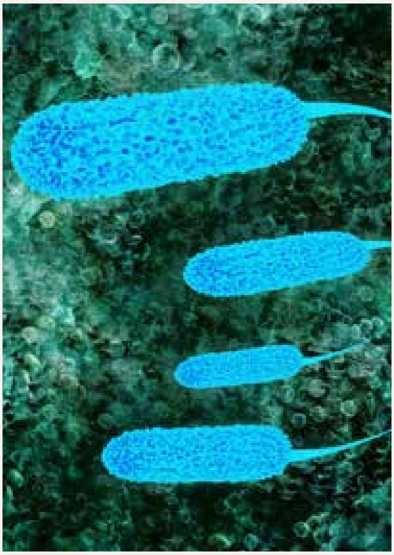
FIRST PERSON

Stephanie Hays

What does your research involve?
E. coli bacteria are often optimised to produce biofuels or useful medicines or chemicals. But the *E. coli* still need to be fed sugars to grow, and growing that sugar can take up space needed to grow food.

I am trying to engineer photosynthetic microbial communities of cyanobacteria and *E. coli*. The cyanobacteria capture solar energy and provide sugars to the culture. The aim is to produce *E. coli* that do not need to be fed sugar, which would mean you're not competing with land that could be used to grow food. The bacteria could be grown anywhere from out at sea to a desert, as long as you had sunlight and a closed environment.

What else is being done in the system biology department at Harvard?
I work in Pamela Silver's lab, where there is a very broad range of work going on - from development of artificial human chromosomes, to carbon-fixing cyanobacteria, to work on gut proteomes. The thing that binds all the work is that they combine systems biology and synthetic biology.



E. coli bacteria in a 3D rendered illustration

What does a typical day involve? Is it mainly lab work or computer modelling?
I'm definitely a wet-lab person. The system I work with is not well understood – we have nice models of *E. coli* and cyanobacteria, but when you put them together they do things you wouldn't expect. I'm hoping to move to a more computational model when we have more measurements and data from the system.

How did you get into systems biology? Presumably not many people think 'I want to be a systems biologist when I grow up'.
From an early age I've liked the idea of symbiosis – how one thing depends on another. It's so complex and hard to explain how that works. I also wanted to do something that is really quantitative – I didn't want to be one of those scientists where you just believe what you think is going on without having the solid numbers and data to really back it up and understand.

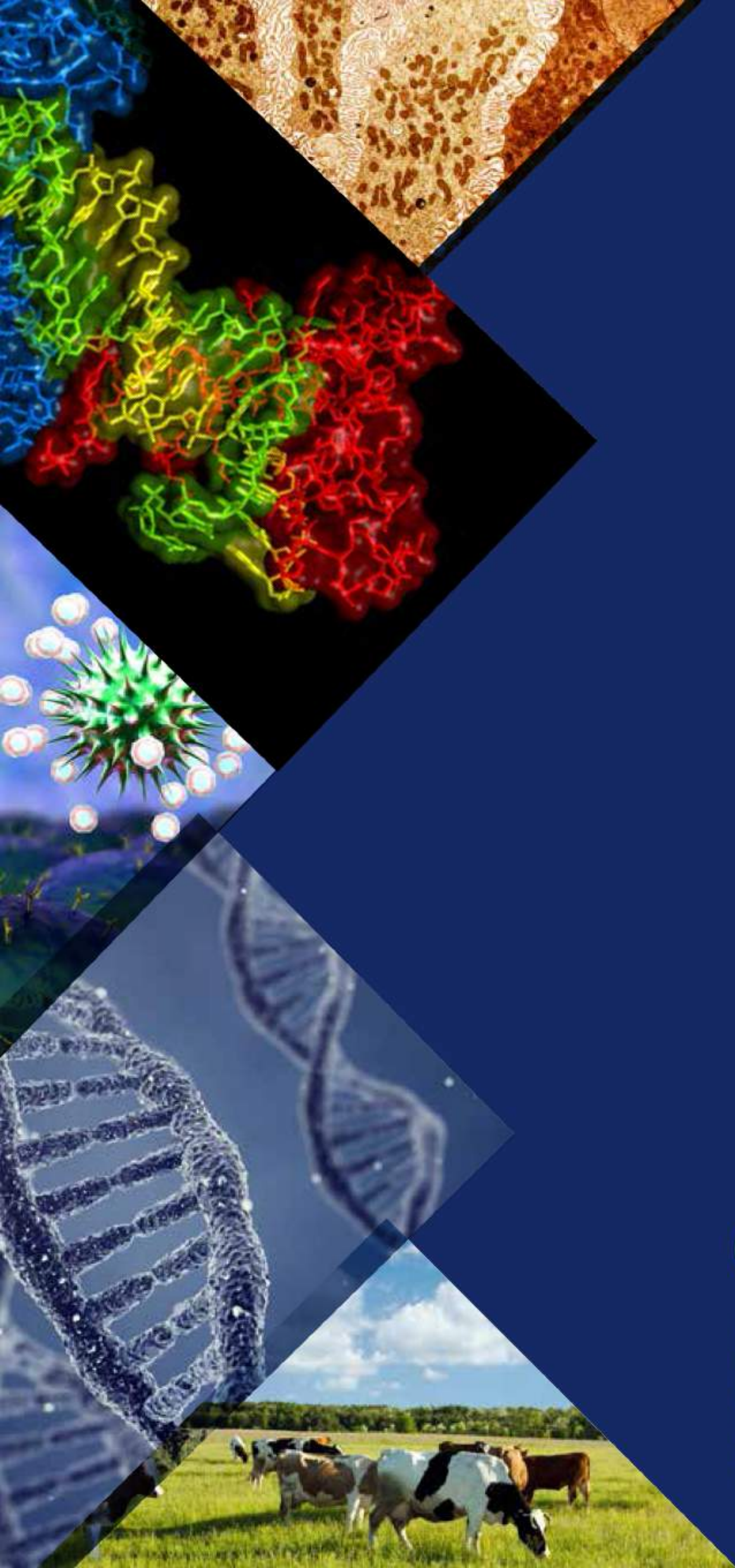
How would you define systems biology?
In our department we have tried to define it a bunch of times. It's interdisciplinary, using everyone's expertise. Instead of looking at individual components in isolation you try to look at an entire system, whether that be all the interactions between proteins in a cell or in entire ecosystems.

It's also about better measurement of experimental systems – not just taking a cell count for example, but measuring metabolic, proteomics, the secretions of the cells into the media – to get a more comprehensive picture of everything that is going on.

Where do you see the field going in the future?
Quantitative modelling can be applied everywhere. You can apply it to medicine or you can just apply it to research if you want to understand the biology of something. I'd say the discovery of new antibiotics will be one area where it will be particularly useful.

Profession
PhD student, Department of System Biology, Harvard
Qualifications
BSc biochemistry; master's biophysics
Interests
Photosynthetic microbial communities, symbiosis, science education

The thing that binds all the work is that they combine systems biology and synthetic biology



Spotlight on the Life Sciences: A Guide to Biology Careers is a collection of articles and interviews taken from the pages of the Society of Biology's ***The Biologist*** magazine. It covers 24 biological disciplines and the careers within them.

Royal Society of Biology

Royal Society of Biology
Charles Darwin House
12 Roger Street
London WC1N 2JU
Tel: 020 7685 2550
Fax: 020 3514 3204
info@rsb.org.uk
www.rsb.org.uk
thebiologist.rsb.org.uk