Research groups contributing to Biosense

Navigating in a chemical world

Professor Judy Armitage FRS heads a research group in the Department of Biochemistry at the University of Oxford, investigating the molecular basis of motility in a number of different bacterial species and its control by environmental signals.

www.bioch.ox.ac.uk/aspsite/index.asp?pageid=565

Further reading:

Christopher W Jones & Judith P. Armitage. Positioning of bacterial chemoreceptors. *Trends in Microbiology* 2015: 23; 247-256.

George H. Wadhams & Judith P. Armitage. Making sense of it all: bacterial chemotaxis. *Nature Reviews Molecular Cell Biology 2004*: 5; 1024-1037.

Deep breath

Professor Sir Peter Ratcliffe FRS is Head of the Nuffield Department of Medicine at the University of Oxford. With his colleague Professor Chris Pugh, he delineated the oxygen sensing and signalling pathways that link hypoxia inducible factor (HIF) to the availability of oxygen.

www.ccmp.ox.ac.uk/ratcliffe-pugh-group

Professor Christopher Schofield heads a research group in the Department of Chemistry at the University of Oxford that is exploring the chemical and structural basis by which the HIF hydroxylases enable cells to respond to low oxygen, in collaboration with Peter Ratcliffe and Chris Pugh.

www.chem.ox.ac.uk/oc/cjschofield/index.htm

Further reading:

Tammie Bishop & Peter J Ratcliffe. Signaling hypoxia by hypoxia-inducible factor protein hydroxylases: a historical overview and future perspectives. *Hypoxia* 2015: 2; 197-213.

Christopher Schofield and Peter Ratcliffe. Oxygen sensing by HIF hydroxylases, *Nature Reviews Molecular Cell Biology* 2004: 5; 343-354.

Beyond seeing

Dr Stuart Peirson heads a research group in the Nuffield Laboratory of Ophthalmology at the University of Oxford investigating how the light environment regulates physiology and behaviour.

www.eye.ox.ac.uk/team/principal-investigators/stuart-peirson

Further reading:

Steven Hughes, Aarti Jagannath, Mark W. Hankins, Russell G. Foster, Stuart N. Peirson. Photic regulation of clock systems. *Methods in Enzymology*. 2014: 552: 125-143.

Aarti Jagannath *et al*. The CRTC1-SIK1 pathway regulates entrainment of the circadian clock. *Cell* 2013: 154; 1100-11.

The contributions of the following to the content of the Biosense exhibition are gratefully acknowledged:

Beyond seeing Dr Laurence Brown, Dr Sibah Hasan, Dr Steven Hughes, Dr Aarti Jagannath, Dr Stuart Peirson, Dr Violetta Pilorz, Dr Carina Pothecary, Jovi Wong: Nuffield Laboratory of Ophthalmology

Deep breath Professor Sir Peter Ratcliffe, Professor Chris Pugh: Nuffield Department of Medicine
Dr Ian Clifton, Dr Emily Flashman, Saiful Islam, Dr Oliver King, Dr Michael McDonough, Suzana Markolovic, Dr Akane Kawamura, Professor Chris Schofield, Dr Louise Walport, Dr Sarah Wilkins: Department of Chemistry

Living in a chemical world Professor Judy Armitage, Dr Mark Roberts (now at Queen Mary University of London), Dr Nicolas Delalez (now at the University of Warwick), Dr Kathryn Scott: Department of Biochemistry

Exhibition project group Rachel Parle, Wendy Shepherd, Ellena Smith, Professor Paul Smith, Harriet Warburton: OUMNH

Project manager Georgina Ferry

Exhibition designer Claire Venables: Giraffe Corner

BBSRC bioscience for the future

The EPA Cephalosporin Fund

wellcome trust

Museum of Natural History

Oxford University Museum of Natural History
Parks Road, Oxford OX1 3PW

01865 272950
info@oum.ox.ac.uk
www.oum.ox.ac.ul

BIOSENSE

All living organisms need to sense changes in their environments. Current research is exploring the mechanisms involved, and how we might benefit from this understanding

8 May – 31 August 2015

Museum of Natural History

UNIVERSITY OF OXFORD

BIOSENSE

Navigating in a chemical world

Bacteria are among the simplest living organisms, each individual consisting of only a single cell. Yet, thanks to sensors that detect chemical changes in their surroundings, they successfully meet all the challenges of life in a wide variety of different environments.

Bacteria are among the oldest forms of life on Earth, but they were not discovered until the Dutch scientist Antony van Leeuwenhoek developed the first microscopes in the 17th century.

Antany van Leeuwenhoek drew the tiny 'animalcules' he saw under his microscope

WELLCOME IMAGES

Many bacteria can swim towards oxygen, nutrients or light and away from toxic substances by rotating long, corkscrew-shaped filaments called flagella. A rotary motor embedded in the cell membrane drives each flagellum. The bacterial flagellar motor is one of very few examples of rotary motors found in nature. It allows bacteria to travel up to 100 times their body length in a second!

Bacteria that can sense and respond to their surroundings by swimming to a better location have an advantage over those that cannot. Some have sensors on their cell surfaces that can detect light, food or signals from other bacteria. This world of sensations drives the bacterium in the most favourable direction, a process called chemotaxis.

Swimming and chemical sensing are linked to the formation of different kinds of bacterial community. To find out if they are alone or in a crowd bacteria release a chemical into their environment. When they detect high enough levels of the chemical they begin to cooperate: this is called 'quorum sensing'. Biofilms, such as dental plaque, form when bacteria come together and stick to surfaces by excreting a slimy, glue-like substance. Quorum sensing is also crucial to generating the bacterial bioluminescence used by many deep-sea creatures to lure prey or act as camouflage.

Bacteria cause a wide range of infectious diseases. Many bacteria have now developed resistance to some or all of our antibiotics. By studying how they sense and move, researchers hope to develop a new range of antibacterial agents. The same knowledge could help us to make more use of the many positive roles that bacteria play in the natural world.

Deep breath

We need to breathe oxygen to survive. Sensors in our cells respond when levels of oxygen fall to dangerous levels, triggering changes that bring more oxygen to the tissues. Research on the oxygen sensing pathways may lead to new treatments for diseases such as anaemia, stroke and cancer.

Oxygen built up in the atmosphere of the early Earth as the first photosynthetic organisms released it as a by-product. Oxygen allows animal cells to burn fuel to produce energy more efficiently. The increased availability of oxygen led to the evolution of a hugely diverse range of animals, large and small.

The English non-conformist preacher Joseph Priestley first separated oxygen from air and showed that it was essential for life: it was later named by the French scientist Antoine Lavoisier.

At high altitudes people adapt to low oxygen (hypoxia) by producing more red blood cells through the influence of a hormone called erythropoietin (EPO). Special cells in the kidneys increase production of EPO in response to hypoxia: other kinds of cells also sense oxygen in the same way and regulate many other processes, such as the development of blood vessels and how the cells actually use oxygen in their metabolism.

Central to oxygen sensing is a protein called hypoxia inducible factor (HIF). Cells produce HIF all the time, but in the presence of oxygen it is quickly destroyed. When oxygen levels drop, HIF turns on genes that increase production of red blood cells, grow new blood vessels and regulate metabolism to cope with low oxygen.

Oxygen is absorbed in the lungs and transported round the body in the bloodstream

GOA NOVI/SHUTTERSTOCK.COM

When oxygen is plentiful a family of enzymes called HIF hydroxylases 'mark' HIF for destruction. Researchers are now working on the design of new drugs that block the HIF hydroxylases to boost delivery of oxygen in patients with anaemia or cardiovascular disease. Drugs targeted against HIF itself might help to block the growth of new blood vessels in cancer.

Beyond seeing

Our eyes detect light so that we can see. But our brains also use light sensed by the eyes to regulate the daily rhythms of our activity. Understanding this process might help us to cope with shift work and jet lag, and to improve our working environments.

Light from the Sun powers the earth, and to make use of this energy living things need to be able to detect it. The first single-celled organisms developed simple receptors that were sensitive to light. Over time, animals evolved eyes that could also form images. Light-sensitive cells in the vertebrate retina send signals to the brain about objects in the light environment. Several brain areas work together to turn these signals into an image.

Light also regulates our daily cycle of activity. Diurnal animals (including humans) wake up in the morning, and fall asleep when it gets dark; nocturnal animals do the opposite. This circadian rhythm enables animals to anticipate the changes in their environment that occur due to the Earth's daily rotation.

Cells in the retina at the back of the eye respond to light and send signals to the brain

GRAPHIC COMPRESSOR/SHUTTERSTOCK.COM

A master pacemaker in in our brains regulates molecular 'clocks' throughout the body. In 2000 scientists discovered how the master clock is set to the right time. Some of the retinal ganglion cells that relay visual signals to the brain are also directly sensitive to light, and contain a new kind of photoreceptor called melanopsin that is responsible for setting the master clock.

Melanopsin is more sensitive to light at the blue (shorter wavelength) end of the spectrum than the photoreceptors that we use for vision. Different kinds of artificial white light are made up of different combinations of wavelengths. Living under artificial illumination, or working at computer screens at night, may have unwanted effects on our physiology.

We suffer from jet lag when we move between time zones because the clock system has a built-in brake that stops any change in the day-night cycle from happening too rapidly. This discovery might make it possible to develop a drug that would boost the effects of light on the brain's master clock and speed up recovery from jetlag.