Improving Health and Wellbeing:
new advances in medical care

Science & Technology Facilities Council

Foreword

Advances in healthcare bring significant social and economic benefit. Increased life expectancy, improved quality of life; a more active population; a healthier workforce; less pressure on healthcare services and budgets these are some of the prizes that ultimately depend on research breakthroughs in medicine, health and the biological sciences that underpin them.

The STFC contribution in this arena complements the work of our colleagues at MRC and BBSRC, the UK's primary Research Council funders in this field. Our aim is to apply the latest developments in our science and technology to health-related challenges. We do this through funding research, provision of access to outstanding research facilities, extensive collaboration with industry and academia, and in-house research catalysing the creation of dynamic, innovative spinout companies capable of capturing markets worldwide.

The tools which are available to us include harnessing leading-edge laser science, computational science, particle accelerator and neutron-scattering capabilities, micro and nanotechnology, materials science, space science technology and other disciplines. The breakthroughs we make possible benefit the three key dimensions of healthcare: protection, detection and treatment.

Better protection

Prevention isn't just better than cure, it's often cheaper too. We continually extend the limits of medical and biological knowledge and explore new ways of keeping illnesses and diseases at bay.

Better detection

Diagnosing conditions earlier, more accurately and less invasively not only benefits patients but also relieves strain from healthcare resources. Our capabilities have delivered important diagnostic advances covering a range of serious conditions.

Better treatment

Helping treatments to become more clinically effective and, where appropriate, more cost-effective too is absolutely vital to the future health of the nation.

I am pleased to present this small selection of the cutting edge research and technology that STFC and our supported communities have carried out in the field of Health and Wellbeing.

John Womersley, CEO STFC

Space technology targets tuberculosis

Instrumentation developed for an STFC funded space mission is being adapted into a cost-effective, rapid and accurate tool for diagnosing tuberculosis (TB) which kills 2 million people each year

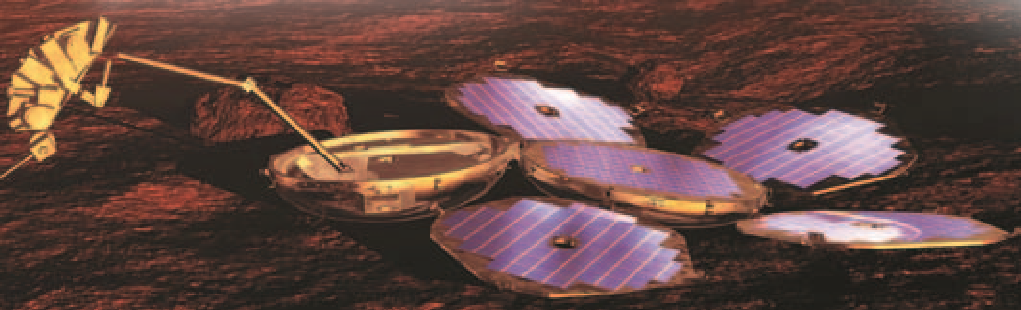
The Wellcome Trust has funded scientists at The Open University and the London School of Hygiene and Tropical Medicine to develop a mass spectrometer capable of detecting TB. The disease, which is caused by the M. tuberculosis bacterium, kills two million people every year, primarily in the developing world.

Specialised instrumentation is required for space missions. An instrument that can identify and quantify unknown compounds called a mass spectrometer was developed for the Beagle 2 mission to Mars. The instrument, designed for analysing samples of Martian soil, will be capable of detecting TB in samples much quicker and with a much greater sensitivity than current methods.

At present, diagnosing TB in poor countries involves using microscopes to examine samples - a very labour-intensive process with low sensitivity. This is not an accurate way of diagnosing TB and only detects a third of all positive cases. That means seven out of ten patients will effectively need their condition to get worse before they can be diagnosed and treated.

The new approach using the spectrometer identifies the unique signature from the bacterium that causes TB. It is also fully automated, so does not require skilled laboratory technicians or special laboratory facilities. This means that the technology will be more widely available in the places that need it most.

This development provides a clear demonstration of how investment in space can lead to advances in technologies which have direct benefit to humankind. The team are now planning to test their prototype in trials in Malawi with the ultimate aim of saving thousands of lives per year.



STFC helps Siemens improve its products

STFC's Technology Department has been working with Siemens Magnet Technology to help improve one of its products; improving their competitive advantage and positively impacting the UK's economy.

Siemens healthcare business is one of the world's largest suppliers to the healthcare industry, employing some 48,000 employees worldwide. In 2009 they posted revenue of 11.9 billion euros. More than 30% of MRI Scanners installed in hospitals worldwide have, at their heart, a Siemens superconducting magnet manufactured by its production facility in Oxfordshire.

In 1995, engineers at the STFC's Rutherford Appleton Laboratory undertook a project with Oxford Magnet Technology (now Siemens Magnet Technology). The project sought to reduce the production times for the company's superconducting magnets used in their MRI scanners. As part of the project, the STFC staff developed a new epoxy resin bonding system. This system both reduced the production time of the product and also reduced the number of times the magnets failed. Since 1995 all new Siemens MRI scanners have included magnets made with the new resin system.

Clearly the overall economic impact that the new resin system has had on Siemens business is considerable. Whilst the company did not want to share the financial gain due to the commercial nature of this information, it is believed that thousands of MRI scanners have been sold by the company since then, with a value of hundreds of millions of pounds.

Helping to combat AIDS

STFC's Synchrotron Radiation Source (SRS) was used map key proteins in the HIV virus, leading to the development of drugs to combat the disease. Millions of AIDS sufferers are now being treated by drugs based on this research, saving at least 1,200 lives each year in the UK alone

The AIDS pandemic is a major cause of human misery and poverty. More than 25 million people have died of AIDS since 1981. In 2007 it killed more than 2 million people worldwide with over 75% coming from sub-Saharan Africa; effecting economic growth, reducing human capital and reducing life expectancy by 20 years in some African countries. There are 2.7 million new infections each year and an estimated 33 million people live with HIV round the globe. Even in Britain where numbers are relatively low, there are an estimated 83,000 people living with HIV, including 10,000 children born to HIV-infected mothers.

World leaders at the UN Millennium Summit pledged to halt the spread of HIV by 2015 as part of its bid to free the world from extreme poverty; these pledges lie at the heart of the Department for International Development's work programme.

The structure of key HIV proteins were solved using data collected on the SRS, most notably the protein known as 'Reverse Transcriptase'. The majority of anti-AIDS drugs target the Reverse Transcriptase protein and are known as anti-retroviral treatments. Without such treatments, someone who has AIDS typically dies within a year.

In countries where therapy is widely available, the life expectancy for a 20-year old HIV-positive person has been climbing steadily and has now reached 60 years. In this country the use of anti-retroviral treatment has been highly effective, producing a steep decline in the number of AIDS cases reported each year - 2,000 in 1994 to around 850 in 1998 and stable thereafter. The number of deaths has also reduced from a peak of 1,720 in 1995 to around 500 a year now.

Thanks to the key underpinning research carried out on the SRS, there is much hope for those in the UK and the rest of the world who suffer from this devastating disease.

Nuclear physics promises earlier detection of brain tumours

A pioneering project led by the University of Liverpool and STFC researchers combining nuclear physics with state-of-the-art technology, is set to revolutionise medical imaging and significantly reduce the time needed to detect brain tumours, improving both diagnosis and treatment

Approximately 5,000 people are diagnosed with brain tumours each year in the UK. They are notoriously difficult to treat because detection usually occurs in advanced stages of the disease, and the average survival rate is only 35% one year after diagnosis. Thanks to a pioneering project led by the University of Liverpool and STFC's Nuclear Physics and Technology Departments, the time taken to detect brain tumours could soon be significantly reduced and tests made more widely available.

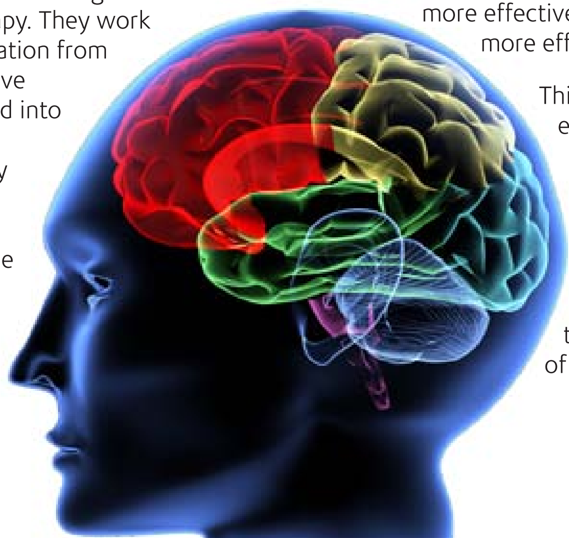
PET scans are currently used to tell if a tumour is growing and whether it is cancerous or benign; they also have an expanding role in assessing a tumour's response to therapy. They work by detecting radiation from a mildly radioactive substance injected into the bloodstream. Tumours normally absorb more of the radioactivity than normal tissue and this shows up on the scan. Widespread use of PET scans is limited by the high cost of the radioactive material.

This collaborative project developed the next generation imaging system by updating the underlying technology using sensors one hundred times more sensitive than those currently in use. This increased

efficiency speeds up patient throughput and lowers radiation doses which in turn will significantly cuts costs and permits more widespread treatment.

PET scans are increasingly used alongside MRI scans, the combination giving information on both the composition of the tumour and its biomedical behaviour. Previously the two technologies interfered so could not be mounted onto a single machine. However, the new technology does not cause this problem, meaning that all existing MRI scanners can be retrospectively fitted with this new system. For patients this means wider access to scanners, fewer appointments, earlier and more effective diagnosis and more effective treatment.

This is a particularly exciting example of how technology emerging from one nuclear physics project, can have a direct and positive impact on the future wellbeing of our society.



Improving neonatal care

Researchers at STFC's Diamond Light Source are gaining a better understanding of premature births to improve prevention, reduce emotional stress for parents and shrink the annual £1 billion cost to the NHS

80,000 babies are born prematurely in Britain every year; with 40,000 having to spend time on intensive care wards. Of the babies that survive many suffer serious complications including lung problems, brain damage, and disability. The role of the amniotic membrane in protecting babies as they develop in the womb is critical and unfortunately its early rupture is one of the most common causes of premature birth and perinatal death.

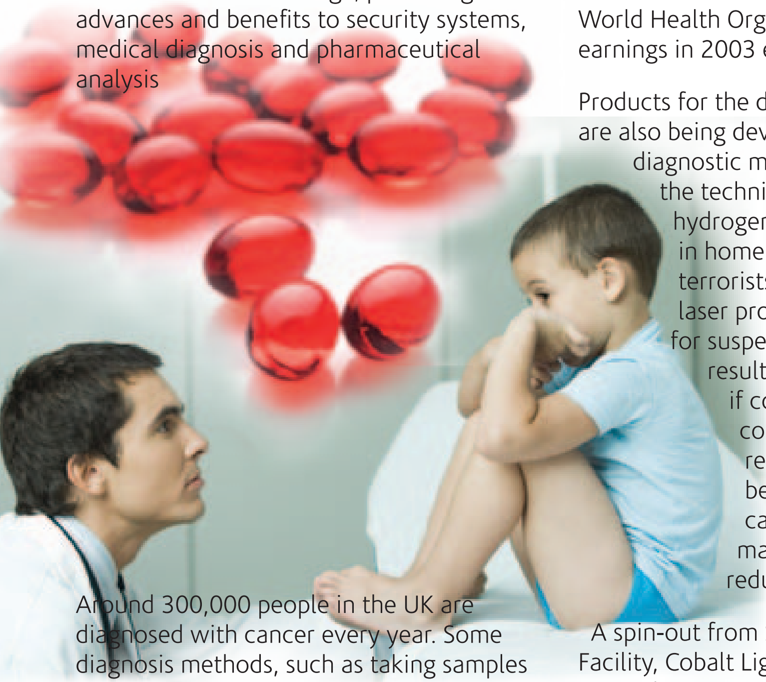
Until recently little was known about what caused the membrane to rupture. Now research collaborators from University College London and Reading University are using STFC's Diamond Light Source to study the amniotic membrane tissue from women who have experienced premature rupture. Early findings suggest that changes in the orientation of membrane molecules weaken its structure leading to tearing before full term.

The annual cost of premature births to the NHS has been estimated at £1 billion with 40% of premature births attributed to premature rupture of the amniotic membrane. A better understanding of what causes the amniotic membrane to tear before the baby is due, will help scientists develop new ways to predict who may be at risk, develop new therapies to lower the number of premature deliveries and substantially reduce the NHS's care costs.

"... our synchrotron work is so important, as it is helping us to build up the results that we need to move this area of research forward." — Dr Che Connon, University of Reading

From cancer diagnosis to drug security

STFC's Central Laser Facility, working in partnership with the NHS, Pfizer ICI and several universities, has developed a technique that can probe deep into solid materials without damage; producing advances and benefits to security systems, medical diagnosis and pharmaceutical analysis



Around 300,000 people in the UK are diagnosed with cancer every year. Some diagnosis methods, such as taking samples of bone for examination, are particularly unpleasant, risky and expensive. A new technique, developed by the STFC in partnership with the Gloucestershire Royal Hospital allows fast, accurate and non-invasive identification, speeding up diagnosis, improving patient care and saving money.

The technique can also be used for the quality control and screening of pharmaceutical drugs. Sensitive probing of objects such as capsules and tablets in blister packs or bottles can be undertaken without opening, allowing the detection of illegal or counterfeit drugs. More than 10% of global medicines are counterfeit, putting patients at risk and undermining revenues of the drug companies; the World Health Organization estimated lost earnings in 2003 exceeded £20bn.

Products for the detection of explosives are also being developed using this new diagnostic method. For example, the technique can detect hidden hydrogen peroxide, often used in homemade explosives by terrorists. In future handheld laser probes could analyse liquids for suspect chemicals and produce results on the spot – even if concealed in a plastic cosmetics jar. The industry response has been strong because the technology can cut the costs of mandatory testing as well as reduce manufacturing time.

A spin-out from STFC's Central Laser Facility, Cobalt Light Systems Limited, was created in 2008 to develop the full range of commercial applications for this non-invasive diagnostic tool. The company has received an Institute of Engineering and Technology Innovation Award, secured £1 million in investment from both the public and private sectors, and won four major contracts from academic, security, medical and pharmaceutical industries.

This is a superb example of how cutting edge science can provide direct solutions for industrial problems and deliver real improvements to our health and security.

Waking up to the side effects of anaesthetic

STFC's Synchrotron Radiation Source helped to create new drug to reverse the post-operative impact of anaesthetics; improving patient care and reducing NHS costs whilst improving revenues for UK economy

STFC's synchrotron radiation sources have been used for decades to improve the drug discovery programmes of pharmaceutical companies by improving their knowledge of key drug compounds and allowing companies to tailor their design. Synchrotron radiation sources can provide results inaccessible to other techniques and companies benefit in two ways – firstly by developing completely new products or by reducing development costs of planned products thereby shortening the time to market. Blockbuster drugs generate revenues of close to £700 million per annum for 10 - 12 years; if the time to market can be reduced by just six months, then this brings forward £330 million revenue for the company and substantial benefits for the UK.

One example is a drug called Bridion developed by Organon Laboratories using STFC's Synchrotron Radiation Source facility. Recently released by Schering-Plough, the drug is the first major anaesthetics advance in two decades. Bridion is a completely new method for reversing the effects of muscle relaxants administered under general anaesthetic, working twice as fast as conventional treatments and eliminating many of the commonly encountered side effects such as nausea and diarrhoea. This removes the need for patients to enter intensive care after surgery, something which currently costs the NHS in England £600 million every year; this drug is a significant step in enabling these costs to be reduced.

Technology for research saves lives

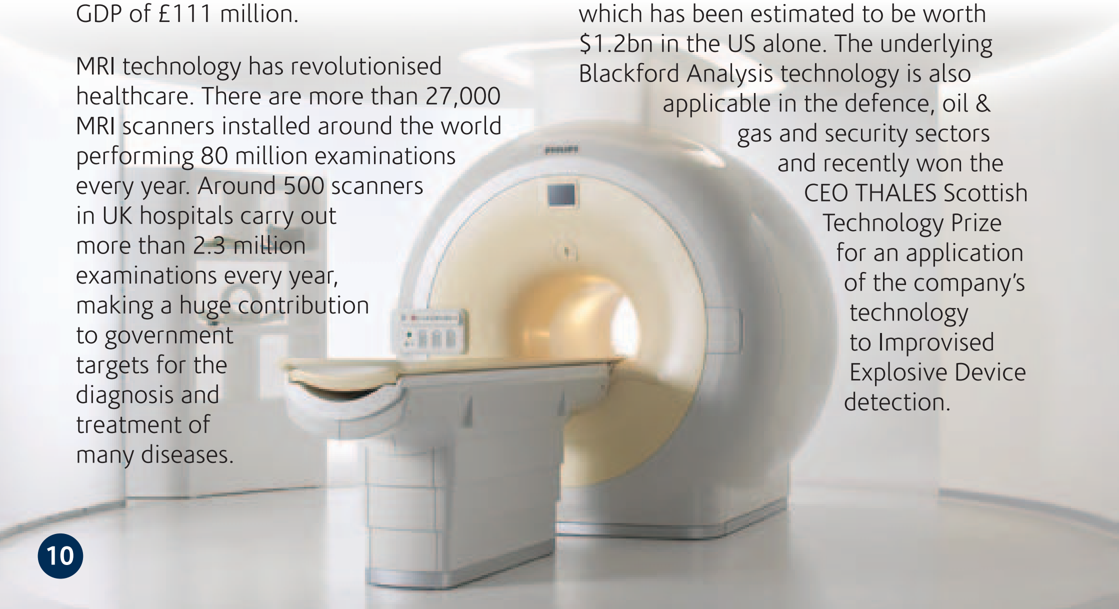
Technology developed to advance STFC-funded research in particle physics and astronomy has underpinned the development of MRI scanners; a £111m industry that saves lives, improves diagnosis and allows more targeted treatment

UK advances in particle physics technology not only supported important experiments at CERN but pioneered early developments in superconducting magnets, which in turn led to the development of MRI scanners. 'Rutherford Cable' is a type of superconducting cable that was invented at STFC's Rutherford Appleton Laboratory for particle physics applications. Now that technology is used extensively in superconducting magnets and a broad range of other applications, including inside every MRI scanner worldwide. This represents a multi-billion pound market for British companies such as Oxford Instruments - the MRI industry supported around 2,200 jobs in 2010, with an estimated value-added contribution to UK GDP of £111 million.

MRI technology has revolutionised healthcare. There are more than 27,000 MRI scanners installed around the world performing 80 million examinations every year. Around 500 scanners in UK hospitals carry out more than 2.3 million examinations every year, making a huge contribution to government targets for the diagnosis and treatment of many diseases.

They can be used to look at almost any part of the body and are often used to speed diagnosis and recovery of patients suffering from conditions that affect the brain and nervous system, eg dementia, strokes and Parkinson's. They are also used to identify damage suffered during heart attacks, or assess damage to cartilage, tendons and ligaments sustained in sports injuries. One of the main advantages of MRI is that unlike X-rays, it does not involve exposing the body to radiation and for this reason it is an import way of monitoring foetal defects in pregnancy.

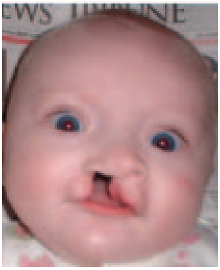
Further developments in MRI scanning have evolved out of STFC-funded astrophysics research. Blackford Analysis is a University of Edinburgh spinout company that uses distant star imaging techniques to stabilise MRI images of moving patients, allowing the elderly and young children to be scanned without anaesthetic. This product also aligns 3D medical scans in real time, increasing radiography throughput by 10% which has been estimated to be worth $1.2bn in the US alone. The underlying Blackford Analysis technology is also applicable in the defence, oil & gas and security sectors and recently won the CEO THALES Scottish Technology Prize for an application of the company's technology to Improvised Explosive Device detection.



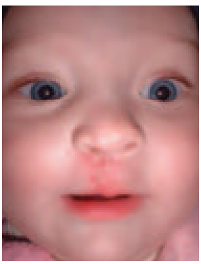
Breakthrough for babies born with severe cleft palates

STFC's ISIS facility and its users, working in partnership with the NHS, developed a novel material to improve the treatment of cleft lip and palate, speeding up healing times and reducing operating costs

Researchers working on a treatment for babies born with cleft palates have made a promising breakthrough. Clefts are the most common birth defect in Britain, with one in every 700 babies affected – that is 1,000 babies per year. Babies born with cleft palates usually have problems feeding, and may have speech difficulties in later life, as well as issues with their hearing, dentition and facial growth and may fail to reach their potential because of low self esteem. In severe cases radical surgery is required, often taking up to ten expensive operations to correct the problem, and future complications can occur as the child grows into an adult.



6 month old girl before surgery to have her lip repaired.



The same girl, 1 month after the surgery

Cleft palates are currently repaired by surgically repositioning the tissue on the roof of the mouth to cover the gap in the palate. However, if the cleft is too wide there may be insufficient local tissue available to close the gap without undertaking quite radical surgery. It is these severe cases that can cause future complications for infants as they develop into adults – particularly with speech and facial growth problems.

The preliminary results on a new material studied using the Science and Technology Facilities Council's ISIS neutron source show treatment for these severe cleft palates could be carried out without the need for complex surgery. The new treatment involves inserting a small plate made of a hydrogel material into the roof of the patient's mouth without the need for complex surgery. The hydrogel developed by Oxford University spin-out Oxtex using STFC's ISIS Neutron Source gradually expands as fluid is absorbed, encouraging skin growth over and around the insert. When sufficient skin has been generated to repair the palatal cleft, the insert is removed and the cleft is repaired using this additional tissue. Clinical trials have taken place and the company has started manufacturing devices, recently winning an award for its "impressive and rapid" progress to market at the OBN Annual Bioscience Awards.

Again the same girl, age 5 years old.

Big science supporting small business

STFC is providing leading-edge shared laboratory space for high-tech businesses at the Daresbury Science & Innovation Campus to improve the efficiency and competitiveness of UK SMEs

Carrying out research and development can be very costly for new or growing businesses. STFC is now providing more than £3 million of state-of-the-art laboratories at its Daresbury Science and Innovation Campus for use by small high-tech start-up companies.

Opened in 2010, STFC's Innovations Technology Access Centre (I-TAC) is located on the Campus and offers businesses and researchers the ideal environment to carry out high-tech R&D. The Centre provides flexible and affordable access to fully-equipped biological, imaging, materials and physical science laboratories. Businesses can either lease their own exclusive-use laboratories or opt for access to multi-user laboratories available on a daily basis.

I-TAC has already supported over 25 companies mainly from the biomedical, energy and environment sectors who have undertaken research and development at the facility. With the creation of 34 new jobs and investment to the companies of over £8.5 million, it firmly indicates the growing success of this unique incubator facility.

An example of an I-TAC user is Bioeden, an international business with an innovative process for collecting stem cells from children's milk teeth. Stem cell treatment to repair or replace damaged tissue and organs will be the cornerstone of future medical science. This process allows parents to preserve and store their children's stem cells for future use. The company is using the space within the ITAC facility for storage of their cell bank.

I-TAC tenants and the other companies on the Campus have greatly benefited from co-location. A recent survey reported that companies have attracted a total of £54m external investment and achieved an average sales growth of 49% per annum since locating onto the Campus.

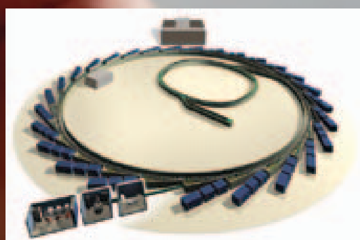
Mapping the brain to help diagnose Parkinson's

STFC is working with the Wellcome Trust to better understand Parkinson's disease; this will allow early detection by conventional methods increasing the efficiency of treatment, whilst reducing care costs and improving quality of life

Each year 10,000 people in the UK are diagnosed with Parkinson's disease and up to 7 million people are touched by the disease in some way. This neurological condition causes tremors, slowness of movement and stiff muscles, making it difficult to walk, write or talk. There is no cure but drugs are the main treatment to control the symptoms and maintain quality of life.

There is currently no cure but Diamond Light Source, the UK's synchrotron, is helping scientists better understand the brain's chemistry to help early diagnosis and the development of new treatments. Parkinson's disease results from the loss of nerve cells in parts of the brain that produce the chemical dopamine, which transmits messages to areas of the brain that co-ordinate movement. The loss of the nerve cells means that co-ordination is impaired. People with Parkinson's also have abnormally high levels of iron in their brain and researchers from the Universities of Keele and Florida, funded by the Engineering and Physical Sciences Research Council, were able to investigate this condition at the Diamond Light Source.

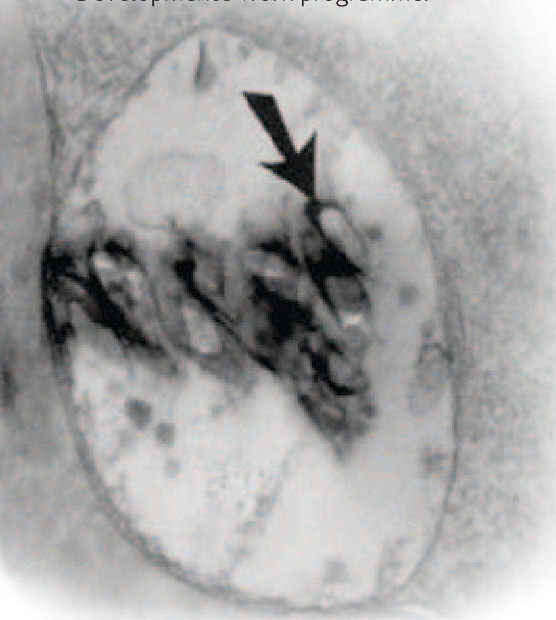
Funded by STFC and the Wellcome Trust, the Diamond Light Source is a large scientific facility which uses intense beams of light, or synchrotron radiation to illuminate and reveal the structure of matter. Researchers at the facility mapped the distribution of iron in healthy and diseased parts of the brain, obtaining information about how the iron is stored at different stages of the disease. This allows early diagnosis which is the key to effective treatment; by the time a typical individual presents symptoms, the disease may have already caused significant brain cell damage. These advances should provide the opportunity for early MRI detection and diagnosis, hence helping to control the disease and improve the patient's quality of life.



Reducing the devastation of malaria

STFC's Synchrotron Radiation Source was used to understand how conventional anti-malarial drugs work, allowing the development of more effective treatment to reduce the devastating global impact of malaria

Malaria is one of the planet's deadliest killers and the leading cause of sickness and death in the developing world. Each year there are 350–500 million cases of malaria worldwide, with fatalities between approximately one and three million people per year, the majority of which are children under five. World leaders at the UN Millennium Summit in New York pledged to combat this disease as part of its promise to free the world from extreme poverty by 2015; these pledges lies at the heart of the Department for International Development's work programme.



An electron micrograph of a malaria parasite inside a red blood cell

Although anti-malarial drugs such as quinine can help to prevent the contraction of malaria, no-one knows exactly how they work. In 2005 researchers at STFC's Synchrotron Radiation Source facility worked with researchers from Cape Town University in South Africa to investigate how the drugs worked. They were hoping to produce readily available and more effective drugs that would protect people in developing countries from this killer disease.

One theory about how the drugs prevented people from getting this disease was through the interruption of a vital part of the malaria parasite's digestion pattern. Malaria parasites survive by eating the haemoglobin in blood cells; part of which is toxic. The parasite survives by converting it to a harmless pigment which it stores inside its body. Anti-malarial drugs are believed to work by preventing the formation of the pigment. The research will be used to develop pigment inhibitors, ultimately leading to a cheap and effective drug.

A mosquito drawing blood, Copyright: Gregor Buir @ Shutterstock

Helping to tackle hidden hunger

The STFC funded Diamond Light Source is being used to research the cause of a malnutrition problem which affects more than half the world's population

Micronutrient malnutrition, or so-called hidden hunger, afflicts billions of people. It is caused by a lack of micronutrients in the diet. Fruits, vegetables, and animal products are rich in micronutrients, but these foods are often not available to the poor. The consequences, in terms of malnutrition and health, are devastating and can result in blindness, stunting, disease, and even death. Hidden hunger affects health but also compromises socioeconomic development, learning ability and productivity.

Micronutrient malnutrition is a serious health problem world-wide. High-yield strains of wheat introduced over the last 40 years have also resulted in an appreciable decrease in concentrations of micronutrients found in grain.

Scientists are studying newly developed lines of wheat which contain a higher iron content using the STFC funded Diamond Light Source. Along with a team from BBSRC institute Rothamsted Research, they devised a technique that allows them to pinpoint the exact location of essential nutrients such as iron and zinc simultaneously in wheat grains. For the first time, this has allowed the discovery of the wheat's chemical composition, enabling the scientists to investigate the nutritional value to people's diets.

The technique offers hope for the acceleration of wheat biofortification, which can be used to increase the iron and zinc content of wheat products. If successful, the new lines could be made available to farmers as a cost-effective means of tackling malnutrition, a solution within the economic reach of the world's poorest people and a powerful weapon in the fight against hidden hunger.

"At Diamond, we are now able to discover the chemical composition of the wheat, which will enable us to establish whether the nutrients are readily digestible and can offer enhanced nutritional value to people's staple diets" — Dr Andrew Neal, Scientist at Rothamsted Research

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