Biology to benefit society

Dedicated teams in specialised labs achieve impressive success…

Plants are the ultimate non-polluting, green factory. They produce not only the human essentials of oxygen, food, clothing and shelter, but also a host of valuable chemicals ranging from medicines to industrial oils, flavours and fragrances – and they do this using only energy from the sun, nutrients from the soil, carbon dioxide and water.

Based at the University of York, the Centre for Novel Agricultural Products is dedicated to realising the potential of plants and microbes as green factories and developing new, renewable resources from them, with the help of gene discovery and germplasm development. Novel, plant-derived products under development at CNAP include: optimised plant oils for skin care, perennial grasses that detoxify contaminated land, and high yielding medicinal herbs for production of anti-malarials. CNAP was awarded the Queen's Anniversary Prize for Higher and Further Education in 2006, in recognition of its role as a centre of excellence for strategic research on plants and microbes.

CNAP operates as a strategic research centre within a university setting, occupying 2,000m^2 of dedicated space in specialised laboratories clustered around the CNAP Plant Genome Facility and the Biology Department's Technology Facility. Dedicated teams focused on key activities – including metabolite profiling, bioinformatics and molecular breeding – deliver high throughput data collection, data mining and screening for improved varieties.

At any one time there are 80-100 postgraduate students, postdoctoral, technical and administrative staff carrying out research and support

activities under the guidance of professorial staff and research fellows. In this way, CNAP benefits from a critical mass of cutting-edge technologies and creative scientists with many of the strategic projects being jointly led by senior staff with complementary expertise.

Tackling malaria through fast-track plant breeding

With funding from the Bill & Melinda Gates Foundation, a team of around 30 scientists, led by Professors Ian Graham and Dianna Bowles, is rapidly developing improved, non-GM, Artemisia varieties with the help of the latest genetic and analytical techniques. Their studies have resulted in the first genetic map for the plant, published in Science earlier this year. The map represents a major advance in our understanding of Artemisia genetics and makes it possible to produce new varieties much faster than before. The CNAP team uses the genetic information from the map, as well as metabolomic and agronomic data, to generate a pipeline of increasingly high-performing Artemisia hybrids. These are now being field-trialled in the major commercial growing regions of Africa and Asia. The project is on track to deliver the first of the new hybrids to commercial growers from 2011 onwards; in time to supply rapidly escalating demand for Artemisia-derived malaria drugs.

Other work in CNAP addressing human health issues includes the identification of small molecules from plants that directly affect the immune system. Professor Bowles, in collaboration with Professor Paul Kaye, director of the Centre for Immunology and Infection, is exploring how plant-derived compounds impact on the immune system with the aim to develop new insight and tools to address the increase in immune-related disorders particularly prevalent in Western populations.

Liquid biofuels from plant biomass

Plant biomass offers huge potential as a renewable source of liquid fuel, but to realise this, the major challenge of cost-effective conversion of woody material to sugar has to be overcome. Work carried out in CNAP and published this year in PNAS (King *et al.*, 2010) demonstrates how nature itself can offer up solutions. Sequencing of genes from the gut of the gribble, a small crustacean wood

borer that lives in the sea, led to the discovery of a suite of genes from this organism that are responsible for the conversion of the woody material to sugar. The idea to target this organism for discovery was based on the fact that it has a sterile gut but can survive on a diet of wood, which means it produces all the enzymes to break down the wood itself. Professors Simon McQueen-Mason and Neil Bruce are leading a team focused on characterisation of the gribble genes and their biotechnological development with funding from the BBSRC Sustainable Bioenergy Initiative.

Cleaning up military training ranges

The explosives RDX and TNT are widespread contaminants at military training ranges. Both these compounds are highly toxic, accumulate in the soil and contaminate water that is destined for human consumption. Professor Neil Bruce leads a team funded by the United States Department of Defense that is developing plants such as perennial grasses and poplar trees that grow on contaminated soils by taking up the RDX and TNT and converting them to harmless molecules that can be used to support plant growth. This technology requires the production of genetically engineered plants since they contain genes isolated from bacteria that have evolved to degrade RDX and TNT (Rylott and Bruce, 2009).

Increasing plant growth at lower temperatures

Many British crops are winter varieties that are sown in the autumn and harvested the following summer. Not surprisingly, crops that can grow larger during the lower temperatures of autumn, winter and spring have the potential to yield more biomass and larger numbers of seeds. Work led by Dr Steven Penfield, a Royal Society Research Fellow in CNAP, has led to the discovery of a gene that regulates plant growth at lower temperatures (Sidaway *et al*., 2010). This discovery, funded in part by the BBSRC, was made using the model plant *Arabidopsis thaliana*. The aim now is to partner with industry to establish if this same gene can be used to increase the growth and yield of crops grown at lower temperatures.

Biorefining plant-based feedstocks

It is widely recognised that renewable oils and specialty chemicals have a significant role to play as bio-based feedstocks in a sustainable chemical and fuel industry. The raw material for biorefining can be obtained from either growing dedicated biorefinery crops or sourcing 'waste' materials from other industries such as food and biofuels. It is recognised, for example, that a financially sustainable biofuels industry will be dependent on capturing additional high-value streams from bio-based feedstocks.

Professors Ian Graham and Simon McQueen-Mason of CNAP are working together on the development of hemp as a dedicated biorefinery crop for the UK. Previous funding from the Technology Strategy Board enabled a very successful programme with Boots the Chemist focused on hemp seed oil, and resulted in the development of new skin care products. The aim now is to develop hemp varieties as a source not only of oil but also of fibre, fuel and high value chemicals. Professor Robert Edwards and his group are new recruits to CNAP, and they are focused on biorefining the by-products of wheat-derived bioethanol to obtain high value chemicals that can be used in the flavour and fragrance industry. This work recently received funding from the BBSRC IBTI (Integrated Biorefining Research and Technology) Club.

Several new biofuel factories are currently being commissioned on the east coast of Britain, requiring millions of tonnes of plant-based feedstock with approximately only half of it being used for biofuel. The challenge now is to ensure maximum value is extracted from the other half.

Opportunities such as this have led the University of York to establish a relationship with the Food and Environment Research Agency (Fera) and Science City York that is bringing together CNAP's expertise in feedstock development with demonstrator scale extraction and processing facilities on the nearby Fera site. The aim is to build on the successful CNAP model and establish York as a centre of excellence in biorenewables, performing world-class research and working closely with industry to develop new environmentally friendly products for the 21st Century.

CNAP was founded in 1999 by Professor Dianna Bowles, with the help of a benefaction from the Garfield Weston Foundation. Research in CNAP is funded by UK Government Research Councils, charitable organisations, EU Framework programmes, and industry. The current annual spend in CNAP is £5.2m with total competitive open funding in financial year 2009-2010 of ~£22m. More than 50% of CNAP's income is from overseas organisations, demonstrating the global competitiveness of, and demand for, CNAP's activities.

References

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THE UNIVERSITY of York

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CENTRE FOR NOVEL AGRICULTURAL PRODUCTS

BIOLOGY TO BENEFIT SOCIETY

Professor Ian Graham
CNAP Director

Centre for Novel Agricultural Products
Department of Biology
University of York
Wentworth Way
Heslington
York YO10 5DD

Tel: +44 (0)1904 328750
Fax: +44 (0)1904 328762

ian.graham@york.ac.uk
www.cnap.org.uk