Introducing Our Research
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The global challenges facing society – including sustainable development, and access to clean water, energy, health and good nutrition – require interdisciplinary research and greater innovation in our preparation for the future.

Surmounting the challenges we face today will require a strong emphasis on adapting to climate change, and the solutions will include developing carbon sequestration methods, managing the nitrogen cycle, restoring and improving our urban environment, improving industrial energy efficiency, engineering tools of scientific discovery and restoring and enhancing our fresh water resources. These call for a rapid increase in scientific capacity.

The Faculty of Science & Engineering has an international reputation for research, assisted by some of the world’s most advanced laboratory equipment, and so our staff are well-placed to address many of these challenges as articulated by New Zealand’s National Science Challenges and the UN’s Millennium Development Goals.

But we don’t just have a future-focus. Our scientists have the capacity and flexibility to respond to immediate issues. That was clear when the Rena ran aground in Tauranga Harbour in 2011, when Waikato scientists mounted an immediate response survey of marine species within two days of the ship’s grounding. University of Waikato scientists identified the ship’s oil composition, and tracked its flow, and we continue to provide on-going environmental advice.

Working alongside our School of Science, our School of Engineering has established a strong reputation for applied research, serving New Zealand agribusiness, and new and emerging fields – such as biopolymers, mechatronics, optoelectronics and titanium alloys – to seek out opportunities for new technologies.

We welcome enquiries from industry, government agencies and other potential partners. This booklet will give you more information about what we do, and what we can do for you.

Professor Bruce Clarkson
Dean
Faculty of Science & Engineering
Much of our scientific research involves collaboration with business, other research institutes and local authorities, impacting and advancing research and development.

Introducing Our Research

For nearly 50 years we have been teaching and researching science at the University of Waikato. Engineering is a much newer discipline for us, but during its short life the Engineering School has grown to rival the School of Science and all five engineering programmes are accredited to IPENZ – the national institute for professional engineers.

Much of our scientific research involves collaboration with business, other research institutes and local authorities, impacting and advancing research and development all over New Zealand and around the world. Part of our success is due to our investment in world-class research equipment and facilities, some of which are also available for external contract work (see pages 30-31).

The Faculty has a dozen specialist research centres, groups or units (see page 29), including the Coastal Marine Group, and Coastal Marine Field Station in Tauranga, and the Radiocarbon Dating Laboratory which has been operating for more than 35 years providing radiocarbon assays for clients from around the world. The lab has been at the forefront of research into the dating technique and its application in the disciplines of palaeoclimate and archaeology. The Faculty also hosts the Environmental Research Institute which undertakes multi-disciplinary environmental research across a range of ecosystems to inform policy and practices that will support effective environmental outcomes. Staff are earning an international reputation for natural heritage restoration.

Our scientists have been making field trips to Antarctica since 1969 and today the University of Waikato’s International Centre for Terrestrial and Antarctic Research (ICTAR) works closely with Antarctica New Zealand. All Antarctic expeditions form part of the official New Zealand Antarctic programme.

Each expedition produces an immediate science report, which is distributed by Antarctica New Zealand. Much of our current Antarctic research is undertaken in collaboration with Landcare Research or relates to impacts of human activities on the Antarctic environment.

The Cortical Modelling Group – comprised mostly of physicists – works with the Waikato District Health Board on finding how the brain functions during anaesthesia and sleep.

While much of our research is out in the field, we’re also developing innovative applications of Geographical Information Systems, classifying visual landscape character and the use of GIS for biodiversity mapping and modelling.

In the world of chemistry our services are used for analysis and identification. Inductively coupled plasma–mass spectrometry (ICP-MS) is the accepted and most powerful technique for the analysis and quantification of many elements in liquid or solid samples due to its speed, precision, and sensitivity and for this reason, our services are widely used.
The launch in 2011 of the Environmental Research Institute (ERI) brought the University’s internationally acclaimed environmental research programmes under one roof.

The institute tackles some of the big problems New Zealand faces in environmental degradation and biodiversity decline, and builds on the University’s significant strengths in terrestrial, freshwater, coastal marine and Antarctic ecosystems.

Restoration of the Rotorua Lakes is ongoing while ERI’s coastal marine ecosystem research is centred on Tauranga, and focuses on ways to better manage the environmental well-being of coastal areas given the increasing pressure and conflicts of use from urban development, aquaculture, recreational and commercial interests.

Dr Daniel Laughlin, senior lecturer in biological sciences, is one of a team of researchers developing and testing a model that can predict where plant species will grow and how their distributions may shift in response to changes in environmental conditions.

In Hamilton city, big changes are taking place as ERI staff and students work to bring biodiversity back into the urban area, with different natural ecosystems being reconstructed in gullies and on ridges, hill slopes and wetlands.

In Antarctica, Professor Craig Cary leads a team studying microbial ecosystems to provide a microscopic view of how biodiversity is influenced by physicochemical factors such as surface temperature, soil geochemistry, water availability, and soil texture and composition.

Environmental Science: Biodiversity and Biosecurity

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Climate Change

The Faculty is tackling climate change from many angles, from plant stress as a result of environmental change, to the change in permafrost conditions and microbial changes in Antarctica as a result of warmer temperatures.

Our researchers are investigating how weather changes are affecting farmers across New Zealand as well as how weather changes are affecting maize production in China.

In Northland, swamp kauri may hold secrets about climate change. Associate Professor Alan Hogg is using radiocarbon dating to date tree rings (dendrochronology) to compile a timeline of changes in climate going back millennia.

Climate change has also been identified as a factor in human evolution. Dr Alison Campbell in biological sciences was part of a study that found evidence of an extreme and prolonged drought in East Africa, spanning 135,000 – 75,000 years ago – which may have been the reason why people left Africa for Europe and Asia.

Professor David Lowe is leading a Marsden-funded study jointly with colleagues at Adelaide University to examine how volcanic soils preserve carbon and whether they offer a new tool for reconstructing palaeoenvironments.

Dr Willem De Lange studies tsunami and storm surge prediction, coastal processes and climatic hazards in relation to how these processes may change in a changing climate.

Associate Professor Earl Bardsley is researching means of predicting annual rainfall to help us prepare for dry years.
Sustainable Land Use

Sustainable land management means integrating land, water, biodiversity and environmental management while still meeting food production demands. New Zealand has a sustainable land management programme, but it requires input from many sectors, including farming, industry, oil and mineral extractors, rural and urban authorities and the general public. It’s complicated and rather like an ill-fitting jigsaw.

Scientists are working to find ways to fit the pieces together. Professor Louis Schipper’s focus is nitrogen. He’s researching nitrogen cycling particularly denitrification and how it might be manipulated in agricultural environments. He’s also studying long-term changes in soil organic matter in pastures and nitrogen saturation of organic matter.

Dr David Campbell’s research interests span soil, vegetation and atmosphere. His current research focus is on the environmental drivers of CO₂ and water vapour exchange in peat wetlands (collaborating with Landcare Research), and the effects of farm management practices on farm-scale CO₂ exchanges (associated with the NZ Agricultural Greenhouse Gas Research Centre).

Computational chemist Dr Joseph Lane has a $345,000 Marsden Fast-Start grant to study the impact of nitrous oxide or laughing gas on climate change. He believes nitrous oxide has serious consequences when emitted into the atmosphere, and is the biggest current contributor to the ozone hole.

Health and Biomedical Innovation

Waikato scientists work across a range of health-related disciplines. Medical physicist Associate Professor Howell Round and a colleague in Australia developed a system called TEAP for the education, training and accreditation of medical physicists in clinical practice for Australasia. It’s for physicists who oversee the installation and safe operation of machines used for treating cancer (radiation oncology), as well as in nuclear medicine and radiology. The programme’s adoption by the International Atomic Energy Agency is testament to its value.

The Cortical Modelling Group has developed a physics-based model of the brain to understand the mechanisms of anaesthesia, sleep and cognition, while other researchers are examining surfacing techniques to improve the effectiveness of medical implants.

It could be that the world’s oceans hold the key to a cure for cancer. European Union funding supports an international collaboration involving Waikato to investigate these and other pharmaceutical opportunities. On dry land, honey is under the microscope as work is underway to study variations in mānuka tree nectars and to find the optimal conditions for producing honey with the highest levels of antibacterial activity.

Professor Vic Arcus is studying organisms that spread disease and finding ways to stop them. He’s also co-principal investigator on a project designed to examine the evolution of a network of enzymes that facilitate cellular metabolism by resurrecting and examining ancient enzymes.
Major Research Themes

Sustainable Industry

There are many components that make an industry sustainable. A sustainable industry anticipates economic, environmental and social trends to minimise risk and takes opportunities to improve comparative advantage. Science has a key role to play.

Chemical engineer Dr Johan Verbeek has invented a novel manufacturing process that’s turning low-value animal protein into high-value biodegradable plastic. Associate Professor Mike Duke and his students developed a dibbler that enables trees to be planted consistently in straight lines so pine seedlings grow straight, resulting in improved productivity by 30%.

With New Zealand’s resources of wood and other natural fibres, there is great potential to develop renewable and cost efficient structural composite materials. Professor Kim Pickering specialises in composite research, analysing composites’ short and long-term behaviour and the potential for mass production as well as customised production through 3-D printing.

Professor Peter Kamp and colleagues in the Energy Research Group are studying ways to improve energy efficiency in dairy and timber processing plants. The research could save up to $20 million in energy costs at current levels of production.

A Solar Energy Group is working with industry to integrate solar energy systems into roofing panels, while a power electronics team is developing new supercapacitor-based techniques for energy recovery, power security and optimised hot water efficiency.

Industry-targeted Research

3D printing and 3D imaging are revolutionising industry and the University of Waikato is leading research in both areas.

Titanium alloys are used to make objects by an additive manufacturing process called laser sintering or selective laser melting – a form of 3D printing. At the Waikato Centre for Advanced Materials, researchers are looking at ways to use titanium in products currently made from steel, to reduce weight and increase corrosion resistance.

At Waikato’s Chronoptics lab Dr Adrian Dorrington has developed a 3D range imaging system that has gained an international reputation for its resolution, precision and accuracy.

In other applied research, the Waikato Agritechnology Group has built a dibbler that has improved treestock productivity for plantation planting by up to 30%. Applied optics is a focus for Associate Professor Rainer Kunnemeyer who is using laser, spectroscopy, biophotonics and optoelectronics to find new ways to grade our fruit and to measure the quality of our food, including milk, meat and eggs. Dr Mark Lay is developing new separation techniques using chromatography, while Dr James Carson is modelling thermal processes, including refrigeration and drying, to improve food conservation and security together with an increased shelf-life for export to distant markets.

Professor Sinniah Ilanko is investigating the stability and vibration behaviour of mechanical and structural systems, focusing on analytical methods, while research by our earth scientists is helping exploration companies to locate potential oil and gas reservoirs.

With the pressure on for New Zealand to produce more engineers, the Engineering Education Research Unit is researching ways to use threshold concept theory to enhance teaching and learning, enabling students to understand key concepts from which other knowledge flows.
The challenge ahead is to promote national collaboration on a high-level strategy for biosecurity surveillance which would identify the key areas on which to focus research.

New Zealand is renowned globally as a leader in biosecurity and for its understanding and management of biological introductions. Biosecurity is inextricably linked with the University’s focus on bio-heritage, restoration ecology, stream and lake health, as well as the monitoring of the coastal marine environment through the Tauranga-based Coastal Marine Field Station.

Professor Chad Hewitt, a world-leading expert in the field of marine biosecurity, says the University has developed a wide breadth of knowledge in the field of biosecurity across terrestrial, fresh water and coastal ecosystems – perhaps one of the most significant concentrations in the country.

Our work crosses all aspects of the invasion process, from prevention through to pest and disease management. This is demonstrated by the research conducted into understanding the risks of new species arrivals through vessel activity, the development of a world-first early detection test for the invasive algal species didymo that is now used throughout New Zealand, and the management of pest species such as stoats, koi carp and other pest fish.

Protecting our ecosystems from invasive pests

The challenge ahead is to promote national collaboration on a high-level strategy for biosecurity surveillance which would identify the key areas on which to focus research.

The strategy would aim to identify the most likely pathways of pest entry into New Zealand waterways; the potential pest invaders; and the invasive species that could have the most negative impact, for example, species that could significantly impact regional aquaculture development.

At a regional level, the University works closely with the Bay of Plenty Regional Council, Port of Tauranga and Waikato Regional Council in ecological monitoring and pest management research. Professor Chris Battershill heads the Coastal Marine Field Station and leads the Rena Long-term Environmental Monitoring Programme as part of the recovery plan following the 2011 Rena oil spill. His team also works closely with the Bay of Plenty Regional Council to eradicate incursions of the invasive pest, Mediterranean Fanworm, which is threatening to take hold in Tauranga Harbour and is among six of the most unwanted saltwater pests in New Zealand.
Protecting freshwater from algal blooms

Blue-green algal blooms are an increasing problem in lakes around the world. Known as planktonic cyanobacteria, the causes of blue-green algal blooms and why they produce high levels of toxins when they mass together, is unknown. Contact with the blooms through activities such as swimming can cause severe illness in humans but also affects a wide range of fish and aquatic life.

"It's when you get this type of algae clustered together, usually along the shoreline where currents or other activity has pushed them, that they start producing toxins at very high levels," says Professor David Hamilton from the University of Waikato’s Environmental Research Institute.

"So while algal blooms in the middle of the lake might not cause too many problems, along the shore it can cause intense sickness in humans and severely affect water quality."

Two suspected causes of cyanobacteria blooms are nutrient run-off from intensive land use such as farming, and climate change. Professor Hamilton and his project team, including Dr Susie Wood from the Cawthron Institute in Nelson, hopes a new research project will identify both the causes of blue-green algal blooms and the relationship between bloom density and toxin production. The project, with $920,000 funding from the Royal Society of New Zealand’s Marsden Fund, is an international collaboration with scientists also studying freshwater lakes in China and Singapore.

"While the focus in New Zealand has been on the Rotorua lakes, there are many freshwater lakes around the world that have this problem and it seems to be getting worse," Professor Hamilton says. "If we can understand what causes these blooms and why they become so toxic, we should be able to not just manage them but to prevent toxin production."

"... algal blooms... can cause intense sickness in humans and severely affect water quality." – Professor David Hamilton, BoP Regional Council Chair in Lakes Management and Restoration
Healthy indigenous ecosystems are vital for life on Earth but the secret life of plants means we are still trying to figure out why different plant species grow and how they respond to climate change.

University of Waikato biological scientist Dr Daniel Laughlin and a team of researchers are developing a model that can predict where plant species will grow and how their distribution may be influenced by environmental changes.

“The ability to predict what we observe in nature is the Holy Grail of ecology,” he says. “But predicting species abundances is crucial if we are to understand the rate and direction of species migration in a rapidly changing world.”

With $345,000 funding from the Royal Society of New Zealand’s Marsden Fund, Dr Laughlin’s research explores how functional traits – heritable properties of plants that impact on fitness and performance – dictate species distributions along gradients of soil fertility and climate.

This new knowledge will then be incorporated into predictive ecological models.

A key stage of the project is the collection of leaf and wood trait data from New Zealand’s commonly-found trees to investigate functional traits that influence plant fitness and growth. The functions of leaf and wood govern rates of photosynthesis and hydraulics which in turn determine plant survival rates in resource-limited environments.

The research is expected to make a substantial contribution to forest restoration, already a global effort where scientists seek to understand the mechanisms of plant community assembly in order to restore ecosystems degraded by pollution, fertilisers, development and climate change.

“Government agencies and community groups are trying to manage these dynamic environments so knowing why particular plants grow where they do and understanding the processes of community assembly will help us restore them more efficiently,” says Dr Laughlin.
Vital clues in Antarctica’s Dry Valleys

Antarctica’s Dry Valleys may hold vital clues for scientists trying to understand the effects of climate change – not just in Antarctica but in more temperate areas of the globe.

Dr Charles Lee, Research Fellow at the University of Waikato’s International Centre for Terrestrial Antarctic Research, is one of a team of scientists studying the ecology of extreme environments through funding from the Royal Society of New Zealand’s Marsden Fund and the New Zealand Antarctic Research Institute. He is investigating microscopic life in the McMurdo Dry Valleys to try and understand the polar region’s long-term glacial history, which in turn will provide new and valuable biological perspectives to assess current and future environmental change in the Antarctic.

Antarctica’s soils were once thought to be sterile but scientists now know that they are actually teeming with microorganisms. Because the Dry Valley ecosystem is relatively simple – higher plants and animals find it difficult to survive – Antarctica’s microbial ecosystems therefore provide a unique view into how biodiversity is influenced by physicochemical factors such as surface temperature, soil geochemistry, water availability, and soil texture and composition.

“We have some fresh data that show microbial communities can respond to specific changes in physical conditions very rapidly and drastically, which can have catastrophic consequences for the ecosystem,” Dr Lee says. “The question is, given the slow metabolism of life forms in such a cold area, how quickly in general will Dry Valley biota respond to climate change?”

Identifying the connection between microbial ecology and glacial geomorphology has potentially significant benefits including efforts to protect or manage this unique environment or to forecast the effects of climate change.

“If we can understand how and why these sensitive microbial ecosystems respond to change, it will certainly increase our understanding of how climate change may affect other ecosystems and environments,” Dr Lee says.
The trees are talking

Northland swamp kauri is helping University of Waikato scientists compile a timeline of changes in climate going back millennia.

The kauri is analysed at the University’s carbon dating laboratory to determine the amount of $^{14}$C in the atmosphere over the tree’s lifespan.

Associate Professor Alan Hogg says because kauri can live for 2000 years, they are unique in providing accurate evidence over long periods. “The trees have been growing in Northland for more than 60,000 years and provide one of the best swamp wood archives. We can get a picture of what the climate was like 30-40,000 years ago when the world was quite different from today.”

The swamp kauri is dug up and cut into slabs, which can then be sent to scientists for analysis.

Associate Professor Hogg analyses the amount of $^{14}$C in the samples, which reflect atmospheric levels at the time of growth. The amount varies in the tree rings mostly because of output from the sun and the amount of carbon stored in the Earth’s various carbon reservoirs, such as the atmosphere, oceans, and biosphere.

“The carbon dating work we do is part of a jigsaw with lots of different pieces – this is one small part. When you put all the parts together you get a clear picture of past climates, including rainfall and temperature. You can then understand the natural cycles of climate change, which in turn helps to understand human-induced impacts upon it.”

“We can get a picture of what the climate was like 30-40,000 years ago...” – Associate Professor Alan Hogg
Many of the colourful layers of volcanic ash seen in road cuttings of the Waikato-Bay of Plenty may hold clues to the past. Waikato University scientists studying the buried soils on these layers are uncovering not only why they sequester more carbon than any other soil, but have also developed a breakthrough method for extracting possible ancient DNA from these buried soils that could provide clues to past environments and climate change.

Professor David Lowe, who is leading a Marsden-funded study jointly with colleagues at Adelaide University to examine how these soils preserve carbon and whether they offer a new tool for reconstructing palaeoenvironments, says the project has offered serious technical challenges. "The buried soils contain allophane, a clay mineral comprising tiny spherules of aluminium oxide and silica formed from the weathering of glass from volcanic ash. These spherules are only about three to five nanometres (or 30 to 50 atoms) in diameter. The mechanisms by which allophane holds and preserves carbon, and possibly ancient DNA, makes it extremely difficult to extract for analysis."

Through a series of experiments using synchrotron radiation at the National Synchrotron Radiation Research Center of Taiwan, and other lab work, Waikato PhD student Yu-Tuan (Doreen) Huang in Professor Lowe’s team has shown DNA is not only bound to allophane through phosphate groups but is also physically protected from microbe attack and degradation by filling voids within clusters of tiny allophane spherules (nanoaggregates).

Doreen Huang, working experimentally with Dr Ray Cursons at the University of Waikato, has also discovered no reagents commonly used could break the chemical bond between synthetic allophane and salmon-sperm DNA that had been added to it in the lab. However, through further experimentation they have devised a new method for DNA extraction from the organic matter-rich allophanic soils. Some of these findings have been published in a chapter in a book Soil Carbon (Springer, 2014), and a paper on the new DNA extraction method was presented at the World Congress of Soil Science in 2014.

Professor Lowe’s team has also been invited to review the field of palaeoenvironmental DNA research for the Journal of Quaternary Science.
Research Case Study – Climate Change

Predicting annual rainfall for hydro lakes

Imagine if we could forecast how much rain was going to fall in New Zealand year by year.

That would enable us to prepare for dry years, control hydro lake levels more effectively and assist farmers with planning.

With assistance from Meridian Energy, Associate Professor Earl Bardsley and PhD student Varvara Vetrova are studying winds and water temperatures in the Pacific Ocean and how they influence rainfall in the South Island’s southern lakes.

"If we can work out how different wind patterns and ocean circulation influence rainfall we will be able to develop statistical models to predict river inflows to the main hydro-storage lakes in the Waitaki hydro-scheme," says Dr Bardsley.

The researchers are testing different environmental variables such as sea surface temperatures and pressures and studying historical data to run a series of analytical tests over different seasons and measuring them against existing data in the Waitaki region. Preliminary results of this work were presented in December 2013 to an International Congress on Modelling and Simulation, in Adelaide, Australia.

To protect our southern lakes from seasonal erosion, Dr Bardsley proposes that instead of using lakes for hydro storage, we should pump water up into a high storage basin when it’s plentiful – namely the natural rock basin of Lake Onslow in Central Otago. This would also provide grid buffer as we move toward renewable energy with fluctuating power output.

"The Onslow Basin is a gift of nature and has the capacity to be the largest energy store in the world," says Dr Bardsley. He is simulating energy systems incorporating the Onslow scheme with PhD student Mohamed Majeed, who presented a paper on the economic value of the scheme to the 2014 New Zealand Electricity Engineers Association conference.
People tend to focus on carbon dioxide emissions... but the reality is that for an agricultural country like New Zealand methane and nitrous oxide emissions are much more important.

—Dr Joseph Lane

Maintaining a healthy atmosphere

Popularly known as laughing gas, nitrous oxide has serious consequences when emitted into the atmosphere: it is the largest contributor to the ozone hole.

University of Waikato computational chemist, Dr Joseph Lane, is studying the impact of nitrous oxide on climate change.

The results of the research could lead to changes in land use, particularly in relation to intensification of farming. The main contributors of nitrous oxide emissions are agricultural soils.

"People tend to focus on carbon dioxide emissions when they are thinking about climate change, but the reality is that for an agricultural country like New Zealand, methane and nitrous oxide emissions are much more important."

Dr Lane has a $345,000 Marsden Fast-Start grant to develop a theoretical model that will ascertain how nitrous oxide is broken down in the atmosphere and he’ll use the model to predict the amount of nitrous oxide being released into the air.

Previous research on nitrous oxide had looked at the gas only as individual molecules, whereas Dr Lane's research will look at nitrous oxide complexes. These complexes were thought to be formed in the low temperatures of the upper atmosphere and could change our understanding of how the gas affects the atmosphere.

"It may be that nitrous oxide has a shorter lifetime in the atmosphere than previously thought or that we’re emitting much more nitrous oxide than we presently think," Dr Lane says.

His work will take three years and include more than a million hours of computer simulations, using the University of Waikato and National eScience Infrastructure (NeSI) supercomputers.
Keeping our soil healthy and productive

Why have soil carbon levels declined in some soils over the past 30 years and can the trend be reversed?

Carbon makes up about 50% of soil organic matter and is critical not only for soil health but is a key factor in managing global climate change because the transfer of carbon dioxide through photosynthesis can decrease carbon dioxide in the atmosphere.

Professor Louis Schipper, Dr David Campbell and postdoctoral researcher Susanna Rutledge from the University of Waikato’s Environmental Research Institute are part of a major research project to investigate whether carbon levels in soils can be increased.

“Carbon content in some soils appears to be below maximum capacity and our research is focused on whether that trend can be reversed and soil carbon levels brought back to their original levels or beyond,” Professor Schipper says.

With funding from the New Zealand Agricultural Greenhouse Gas Research Centre and working in collaboration with Crown Research Institutes Landcare Research, AgResearch and DairyNZ, the team is measuring carbon exchange at adjacent pasture areas at a dairy farm near Waharoa. Comparing results between pasture with a traditional ryegrass and clover mix with a more diverse range of pasture species including ryegrass, clover, chicory, plantain, prairie grass and others, the aim is to see if more diverse pasture species increases carbon soil inputs.

“Farm management practices may hold the key but it’s not a simple challenge,” Professor Schipper says. “But more carbon in New Zealand dairy systems will have multiple benefits, including decreasing carbon dioxide concentrations in the atmosphere, improving soil structure, nutrient and water retention and providing food for the microorganisms that keep soil healthy.”

“... more carbon in New Zealand dairy systems will have multiple benefits…” – Professor Louis Schipper
Biodiscovery in our deep oceans

Could the mysterious depths of the world’s deepest oceans hold the key to a cure for cancer?

Deep water organisms that could form the basis for new drugs is one of the most intriguing areas of science. With an experienced Coastal Marine Group led by Professor of Coastal Science Chris Battershill, the University of Waikato is engaged in a growing number of national and international collaborations focused on marine biodiscovery.

The largest – PharmaSea – will explore deep ocean trenches to discover and develop new microbial strains and bioactive compounds from deep-sea organisms to evaluate their potential as new antibiotics or for nutrition and cosmetic applications. This large-scale, four-year project has €9.5 million EU funding and links 24 research and development partners from 14 countries in field work off the coasts of Chile, Peru, China, and New Zealand, and in Arctic and Antarctic waters.

“If you look at coastal ecosystems at all levels... there may be new ideas and innovative outcomes.”

– Professor Chris Battershill, Bay of Plenty Regional Council Chair in Coastal Science
Unlocking the secrets of mānuka honey

Work is underway at the University of Waikato, led by Associate Professor Merilyn Manley-Harris, to try to understand why some mānuka trees produce high levels of the precursor of bioactivity in mānuka honey, and the optimal conditions for converting it to the active component as the honey matures.

It has been established that the precursor for the active antibacterial agent methylglyoxal (MGO) comes from the nectar of mānuka trees; but there is currently little information about what factors govern the conversion of dihydroxyacetone (DHA) into MGO during the maturation process so prediction of MGO yield is still strictly empirical. There is also no published information that accounts for the variation of DHA content of nectar observed in small scale studies of the trees and which may give rise to observed variation in the honey.

A range of doctoral and postgraduate research is developing scientific models for finding answers to these questions.

Doctoral student Megan Grainger is working to develop the theoretical basis for a computer program to forecast the effect of storage conditions on MGO formation and coincidentally the formation of hydroxymethylfurfural (HMF), an unwanted substance formed in any maturing honey, especially if it is heated. The program, once developed, will be available to beekeepers.

A study of dihydroxyacetone in the nectar of mānuka trees around the North Island has been completed and the results submitted for publication.

Master of Science student Yinying Jie is working on the development of a rapid assay for use in the field to identify suitable mānuka trees for possible breeding. This technology may be of use to landowners looking to improve their tree stocks.

Another doctoral student Maria Revell is investigating the origin of DHA production in the tree; once this is established it will provide a scientific basis for potential manipulation of DHA content of the nectar.
The work of the University of Waikato’s Cortical Modelling Group is helping the medical profession understand more about the brain.

Led by physicist Professor Moira Steyn-Ross, the team has developed a model that can predict how the brain will react in different states. They work closely with anaesthetist Professor Jamie Sleigh from the Clinical School at Waikato Hospital.

The group undertakes EEG simulation and modelling of anaesthesia, sleep and cognition.

For example, they can demonstrate the effect increasing or decreasing a drug dose will have on the brain, whether it will produce healthy or pathological results or perhaps cause a seizure. They are finding out how the brain works in conscious and unconscious states.

“Professor Sleigh was interested in knowing if the brain underwent a change of phase during general anaesthesia,” says Professor Steyn-Ross. “Like the changes water undergoes when it’s turned to ice, what we call a phase transition, and he called us in to assist.”

The researchers found that the brain does indeed change when it becomes anaesthetised, and this unconscious phase is very similar to brain behaviour in the deepest phase of sleep.

By simulating the sleep cycle they are finding out how neurotransmitters affect the stages of sleep. "Our model could show how sleep disorders arise and shed light on healthy and unhealthy brain behaviour and what might be causing any changes. From there you can work out how to stop the brain going down a particular path."

Professor Steyn-Ross says their work is a marriage of biology and physics, a combination becoming more common in medical research. Associate Professor Alistair Steyn-Ross, also a physicist, does all the work on the computation side, and there’s a lot of it; Physicist Dr Marcus Wilson works on the sleep project and Dr Logan Voss is a physiologist who works for the Waikato DHB and assists in the biological modelling.

The Cortical Modelling Group has won two Marsden grants administered by the Royal Society of New Zealand, in 2003 and 2007, and a Waikato Health Research Foundation grant, in 2008, to support its research.
Heart, cochlear, spinal-cord and deep-brain stimulators all deliver therapeutic stimuli through electrodes implanted in the human body. Researchers are looking for ways to miniaturise and improve these electrodes for better health outcomes.

Implants could be made smaller, longer lasting and more effective if a surfacing technique could be developed that reduces the electrode impedance and also avoids activating the body’s natural defences so that impedance stays low. Immune reactions and the development of scar tissue can reduce the effective surface area of the electrodes and limit both the therapeutic stimulus and the battery life of the implant.

Surface roughening technology is not used in implants as it is observed that the advantage of the increased surface area is lost over extended periods of time. This is sometimes attributed to cells in scar tissue ‘clogging’ the induced pores. However, since surface roughening treatments are used as anti-fouling protection for boats, it is clear that not all surface roughness approaches invite the same outcome.

University of Waikato researchers from the Faculty of Science and Engineering, including Professor Jonathan Scott, Dr Ray Cursons, Dr Gregory Jacobsen and PhD student Mark Jones, are working to explain what happens when electrodes degrade in the body and to develop a way to improve the electrode surface area without it becoming susceptible to the body’s natural defences. Professor Scott and Mark Jones have developed an objective method of characterising electrode impedance through the use of a newly-developed fractional-capacitor model of the electrode-electrolyte interface. Applying this should help the team to understand exactly how the electrode impedance is affected by various biological events.

The potential number of beneficiaries for this implant research is large and growing. More than 325,000 people worldwide use cochlear implants to overcome profound deafness. About 100 New Zealanders receive cochlear implants every year. Numbers of patients using deep-brain stimulators have also grown as the treatment has gained approval for more conditions, from essential tremor to Parkinson’s disease.
Biodegradable plastic from animal protein waste

University of Waikato researchers have invented a novel manufacturing process to turn low-value animal protein into high-value biodegradable plastic.

In New Zealand, bloodmeal is produced as a co-product from the meat industry and is available in large quantities, typically used as animal feed or fertilizer. The new product, called Novatein™, uses bloodmeal and standard plastic processing equipment to produce bioplastic with a wide range of applications including seedling trays, plant pots, pegs, and vine clips.

Its unusual ingredient – bloodmeal – offers a cost-competitive, sustainable alternative to petroleum-based plastic resins. Its bloodmeal colour can also be modified, giving it a translucent, honey-coloured appearance.

“For me, the most gratifying thing is being able to use low-value sustainable materials to create a high-value product that breaks down without polluting the environment,” says University of Waikato chemical and biological engineer Dr Johan Verbeek.

This novel bioplastic material can be reformulated, modified and optimised to suit a particular product’s attributes. For example, pots, containers, pegs and weed matting have different characteristics and properties, so the bioplastic formulation would be different for each one.

The research project won a Bayer Innovation Award for Dr Verbeek and his team and has attracted substantial investment from Wallace Corporation Limited in a newly-created University subsidiary company, Aduro Biopolymers LP, to take Novatein to the market.

Further research is now underway to develop second and third generation bio-resins with a wider range of applications.
Digging straight holes

It seems a fairly simple thing, to dig a straight hole, but it took Associate Professor Mike Duke and graduate mechanical engineer Ben McGuinness several months to perfect a machine that drills holes accurate enough to ensure pine cuttings grow straight.

The hole-drilling dibbler was built at Waikato University for treestock company ArborGen, which uses it to drill holes for planting pine cuttings in its nursery beds.

Cuttings that don’t grow perfectly straight are not suitable for planting. ArborGen NZ’s Operations Manager Mark Ryan says the company plants “many millions of trees each year and reject trees are a significant and unwanted expense”.

By drilling consistently deep, straight holes, the dibbler has helped improve treestock productivity by about 30%.

The dibbler – which is towed behind a tractor – is computer controlled and adjustable for type of tree and soil hardness, and can drill holes of different depths and operate at varying speeds. “It’s a very professional piece of machinery that is now fully operational and doing a great job,” Associate Professor Duke says.

The $110,000 project was jointly funded by ArborGen and TechNZ, and shows how an industry request for R&D can be fulfilled by research integrated with the University’s teaching programme.

With a solution for planting out seedlings successfully implemented, ArborGen next asked the University’s third-year mechanical engineering design students to come up with a way to mechanise the seed planting process. Seven prototypes were designed and built and evaluated by ArborGen and the best design is now being developed into a product, with funding from ArborGen.

While planting seeds and dibbling is a major issue for ArborGen, its main problem is harvesting and grading seedlings before they’re planted out. To solve this problem, Ben McGuinness has started a PhD to research and develop a robotic machine that can lift and grade seedlings using a vision system. The research is being part funded by Callaghan Innovation and ArborGen.
The research project has an aim of saving up to $20 million in energy costs at current levels of production.

Increasing energy efficiency in our biggest industries

University of Waikato researchers are helping New Zealand’s biggest companies save millions of dollars by becoming more energy efficient.

The Energy Research Group, led by Professor Peter Kamp, partners with government agencies and companies such as Fonterra, Windsor Engineering and RCR Ltd to identify opportunities for the country’s biggest energy users to become more efficient.

Professor Kamp and his team were awarded $2.07 million funding in the Ministry of Business, Innovation and Employment’s 2013 science investment round for the three-year project.

Together the dairy processing and timber drying industries use about 40% of the primary energy used for industrial process heat in New Zealand. Helping these industry giants become more energy efficient is vital to maintaining or increasing their export competitiveness.

The research project has an aim of saving up to $20 million in energy costs at current levels of production. At Fonterra, for instance, the researchers are looking at the final drying method involved in manufacturing milk powder, a particularly energy-intensive process.

The Energy Research Group’s focus is three-fold: tackling the problem theoretically, experimenting in the laboratory and taking testing equipment into factories.

Being industry-focused and targeting a specific issue within a large company allows the research group to not only save that business money, but take the generic principles learned and apply that knowledge to other users. This kind of strategic thinking is a key part of the process to ensure a factory’s reliability remains the most important priority.

The Energy Research Group has also developed an extensive training programme for energy managers to help them up-skill within the energy efficiency sector.
Powering a sustainable future

With growing global demand for sustainability, supercapacitors could be the key to smarter, more efficient energy and water use in our everyday devices and appliances. Researchers at the University of Waikato, led by Nihal Kularatna, are pioneering the development of new supercapacitor-based approaches for energy recovery, power protection and optimised energy and water use.

Supercapacitors have long been used in the electric vehicle and renewable energy industries to improve battery performance. But now Nihal Kularatna and his team have developed a technique for more efficient low-noise DC power regulators. This not only reduces interference but, in some cases, the extra efficiency can extend the battery life of electronic devices by up to three times.

Another project has seen the development of a supercapacitor-based surge protection circuit to save sensitive electronic equipment from damaging power surges caused by lightning strikes and variable power quality. It offers superior protection to other current methods available and commercial production is underway.

The group’s most recent development project uses supercapacitors for rapid water heating. The first application for this solution may be in New Zealand households, where there is often a 30-60 second delay for hot water – and during this time the cold water stored in the pipes is flushed down the sink. Supercapacitors will instantly heat the cold water in the pipe, and this could prevent up to 12 billion litres of water from being wasted in New Zealand every year.

... supercapacitors could be the key to smarter, more efficient energy and water use in our everyday devices and appliances.
Range imaging cameras build a 3D image of a scene, allowing computers to perceive the world in the same way as humans.

3D imaging for industrial uses

Cutting-edge imaging technology is being developed in the Chronoptics laboratory at the University of Waikato.

Range imaging cameras build a 3D image of a scene, allowing computers to perceive the world in the same way as humans. By measuring the shape, size, and location of objects, computers can read a user’s gesture, making a game controller, mouse or touch screen unnecessary.

It works by projecting light on to a scene and then measuring the time it takes for the light waves to return. With this data, distance can be measured for every pixel, and a 3D scene can be reconstructed in real time.

Dr Adrian Dorrington leads the Chronoptics Research Group at the University and he and his team have developed a range imaging system that has achieved unparalleled resolution, precision and accuracy. The group has gained an international reputation, publishing world-class range imaging measurement results and developing sensor characterisation techniques that are so far unmatched globally.

With applications that extend beyond gaming and into medical imaging and industrial equipment, the Chronoptics Group has taken out patents on its findings and the team is now working on getting its technology into commercial range imaging cameras.
Titanium alloys and 3D printing

Titanium is one of the most common elements in the Earth’s crust. It is very strong and light so that titanium alloys have the best strength-to-weight ratio of all engineering alloys. This makes them ideal for use in the aerospace industry, the chemical processing industry and in the biomedical field where titanium alloys are used for implants, such as hip replacements.

Titanium alloys are used to make objects by an additive manufacturing process called laser sintering or selective laser melting. This is a form of 3D printing and enables the manufacture of parts with complex geometries that would be impossible to manufacture by any other method.

Professor Brian Gabbitas and his team from the Waikato Centre for Advanced Materials (WaiCAM) have been awarded Ministry of Business, Innovation & Employment (MBIE) funding to research novel ways of producing and commercialising high-quality titanium and titanium products in New Zealand.

“One of our projects is looking at how to up-scale the process of using titanium powder to create extruded and forged titanium products,” says Professor Gabbitas. “This could be used for many products which are currently made from steel, but which would benefit from having a much lower weight and good corrosion resistance. Some products for marine applications are currently under development for manufacturing by New Zealand companies.”

The second project is a collaborative one with TiDA (Titanium industry Development Association), Callaghan Innovation, GNS Science and the University of Auckland, focusing on processing technologies.

“New Zealand is becoming a world leader in titanium powder metallurgy.”

“We are] looking at how to up-scale the process of using titanium powder to create extruded and forged titanium products.” – Professor Brian Gabbitas
The good oil

Professor Peter Kamp and his petroleum geology research group assist exploration companies to decide where to explore. “We analyse the character and evolution of New Zealand’s sedimentary basins to establish the petroleum habitats. The knowledge we generate helps reduce geological uncertainty and hence the level of exploration risk for companies. In turn, this helps attract exploration activity.”

The Ministry of Business, Innovation and Employment (MBIE) has funded the research group since 1993. “In the past 20 years we have developed specialist capability to analyse sedimentary basins, including various types of geochronology (dating) to establish the age of formations, the source of sediments, and their thermal history.”

Recently the group has acquired industry-standard software to enable the team to map the stratigraphy (layering) of sediments in the subsurface and offshore areas using seismic reflection data acquired by exploration companies and archived by NZ Petroleum & Minerals (a branch of MBIE).

Professor Kamp and his research team have produced a new model to present tectonic development of New Zealand during which the modern Australia-Pacific plate boundary zone developed. “This model essentially describes how the basement rocks underlying the country have been deformed in response to 800km of right-lateral movement through New Zealand.” This model is essential to understanding the location and development of the sedimentary basins through time as well as the mountains that sourced the sediments to the basins.

The researchers have also developed an animated model of the paleogeographic development of New Zealand through the last 65 million years. “Besides its specific value for helping to predict oil and gas habitats, it’s a useful tool for training industry staff in New Zealand’s geological development, and this is now available to oil exploration companies in New Zealand,” says Professor Kamp.

“We analyse the character and evolution of New Zealand’s sedimentary basins to establish the petroleum habitats.” – Professor Peter Kamp
Engineering Professor Sinniah Ilanko is interested in the stability and vibration behaviour of mechanical and structural systems.

He says structures, like people, undergo more stress when they are less flexible. “So sometimes it is useful to introduce some flexibility in structures to reduce stress levels to ensure they don’t fail. Modelling structural supports is often a challenge. In what is called the ‘penalty method’, a support is modelled as a very stiff spring, but until recently there remained an uncertainty in choosing the right stiffness. Values that are too high cause problems with rounding off errors and lower values may permit support movements.

For about 60 years researchers have been grappling with this problem. But, through an error in his PhD, picked up years later by one of his students, Professor Ilanko has found a way to refine the Penalty Method.

His mistake was to put a negative symbol instead of a positive one in front of a ‘mass’ in a frequency calculation, which led to his discovery that negative stiffness and negative mass produced similar results if their magnitudes are large enough to make the supports effectively rigid.

“One reviewer went as far as to call it ‘black magic’. So in engineering circles ‘negative mass’ is probably still quite controversial but it is heartening to see it being cited and used in a biology journal,” says Professor Ilanko.

The idea of negative stiffness and mass led to a new concept of negative structures.

Professor Ilanko has secured a three-year Marsden Fund grant to study the use of negative structures in modelling voids, cut-outs and holes that are commonly encountered in machine components.
Nurturing innovators for the future

There’s a global shortage of engineers, yet attracting and retaining bright engineering students is a world-wide problem. Addressing this issue, researchers from Waikato’s Engineering Education Research Unit have been looking at new ways of teaching, learning and assessing so that students are challenged, but not challenged so hard they give up.

Their research centres on threshold concept theory (TCT). This relatively new theory provides lecturers with a new perspective, whereby they can balance curricula and refine their teaching. TCT identifies troublesome concepts and is expected to improve students’ ability to come to grips with these few special ideas through different teaching strategies. Professor of Electronic Engineering Jonathan Scott says coming to grips with threshold concepts takes more than learning and memorising facts.

“We identified five very troublesome concepts in early electronic engineering that students must fully grasp before they can make progress. For a practitioner, a threshold concept is obvious, but this isn’t the case with students, and the curriculum doesn’t always match students’ natural cognitive processes,” says Professor Scott. “You can’t rush the learning, but you can adjust the curriculum and refine the assessments so you’re not teaching memorisation, but getting to the nitty gritty of the concepts. It may be that you have to keep coming back to it time and time again, but once they ‘get it’, they’re off and away.”

Professor Scott says they’re encouraged by early results and are also working on ways students can confidently articulate their understandings. “We know that students understand better what they can articulate more clearly.”

The group has shown year-on-year improvement on benchmarked cohorts. This improvement is attributed to TCT-inspired changes to lectures, assessments and tutorials. A new eTutorial system, introduced in 2013, has combined the best of TCT with the advantages of online learning.

“So far the results are good,” says Professor Scott. “It’s all about turning out good engineers that employers want to hire.”

The University of Waikato study has been funded by the government through a Teaching Learning and Research Initiative (TLRI).
We have a large number of active research groups within the Faculty which contribute to our major research themes from different specialist perspectives. They include the following:

**Active Research Groups**

- **Centre for Biodiversity and Ecology Research (CBER)**
  CBER promotes sustainable management and habitat restoration through integrated research into biodiversity and ecology.

- **Coastal Marine Group**
  The Coastal Marine Group is a multidisciplinary group of researchers from across the University with a research focus on the coastal zone and adjacent coastal shallow waters.

- **Cortical Modelling Group**
  The Cortical Modelling Group has developed a physics-based model of the brain to understand the mechanisms of anaesthesia, sleep and cognition.

- **Energy Research Group**
  This group aims to improve industry competitiveness through energy efficiency and conservation. The Group has two divisions: The Industrial Energy Efficiency Division and the Sedimentary and Petroleum Geology Division.

- **Engineering Education Research Unit**
  Researchers from the Faculties of Science & Engineering and Education are developing new insights and expertise for teaching and curriculum innovation in engineering.

- **Environmental Research Institute (ERI)**
  The Environmental Research Institute takes a collaborative, systems-level approach to environmental research to develop insights and expertise related to improving and sustaining the quality of New Zealanders' natural and physical environment.

- **International Centre for Terrestrial Antarctic Research (ICTAR)**
  ICTAR works to protect Antarctica through integrated international research into Antarctic terrestrial ecosystems, assuring New Zealand's continued leadership in this area.

- **Solar Energy Research Group (SERG)**
  SERG has expertise in solar thermal, photovoltaic and optical modelling, specialising in building integrated systems. SERG has the only photovoltaic laminator in New Zealand and test facilities for both photovoltaic and solar thermal systems.

- **Thermophile and Microbial Biochemistry and Biotechnology Unit (TRU)**
  TRU researches microorganisms from extreme environments including thermophilic bacteria, genes and enzymes.

- **Waikato Agritech Group**
  The Waikato Agritech Group aims to improve primary industry efficiency, sustainability and profitability by developing high tech, energy efficient systems. It also draws expertise from the Applied Optics unit, and from the Polymers and Composites Group, which researches new bio-materials made from natural fibres and agricultural waste products.

- **Waikato Biogeochemistry and Ecohydrology Research (WaiBER)**
  WaiBER researches carbon and nitrogen in pastures and wetlands with a focus on identifying ways to increase soil carbon content and methods to enhance microbial processes in order to reduce nitrate losses to waterways.

- **Waikato Centre for Materials (WaiCAM)**
  WaiCAM was formed to develop novel processes for producing advanced materials and near net shape components, and to develop high performance structural and functional materials.
The Faculty of Science & Engineering has a number of specialist research facilities that were established to support university teaching and research, but which are also available for external contract work. They include the following:

### Specialist Research Facilities

**Electron Microscope Facility**

The core instruments of the Electron Microscope Facility are the Hitachi S-4700 Field Emission Scanning Electron Microscope (SEM) with Quorum Technologies Cryo-system, and the Philips CM30 High Resolution Transmission Electron Microscope (TEM). Both have x-ray analytical capability for elemental analysis. The SEM system allows high magnification imaging and elemental analysis of small samples including hydrated materials. Sample type may range from bacteria and plant material to metal alloys. The TEM facilitates high resolution imaging of crystallographic and structural features of very thin samples. The microscopes are used predominantly for research and teaching. The SEM also has commercial applications including the imaging and analysis of contaminants, particularly important in the food, dairy and water industries where quality assurance is important.

**Shallow Water Mapping**

The Faculty’s Coastal Marine Group (CMG) has more than 30 years’ experience in state-of-the-art sampling, measurement and monitoring of shallow water environments. Its strength lies in applying coastal research to real-world issues — providing a scientific basis for resource management from environmental policy to engineering works. Its equipment is customised for use in small survey vessels supporting a range of mapping requirements in offshore and inland locations, particularly in coastal and shallow waters. The Group’s multidisciplinary team can tailor its services to meet research and commercial needs.
Waikato Stable Isotope Research Facilities

The Waikato Stable Isotope Unit (WSIU) offers precision analyses of isotopes of carbon and nitrogen in biological, geological, and chemical materials by isotope ratio mass spectrometry. Isotopic abundance analysis is carried out on two fully automated Europa Scientific 20/20 isotope analysers. Materials may be submitted as solids, liquids, or gases, for example, for breath analyses. Precision analyses of carbon and nitrogen content in solid or liquid samples are also provided with a LECO TruSpec Carbon/Nitrogen Determinator fitted with an autosampler for liquids.

The WSIU provides commercial analyses and also services the needs of scientists at the University of Waikato and their collaborators, promoting the use of stable isotopes in all branches of research. The staff are highly experienced in the use of stable isotopes, both natural abundance and enriched tracers, particularly in biological and environmental research. In 2006 the WSIU was accredited by the International Atomic Energy Agency for analyses of carbon (C) and nitrogen (N) content and isotopes 13C and 15N in plant materials.

Stable Isotope Geochemistry at the University of Waikato is carried out in a separate facility. Measurements of stable oxygen and carbon isotope ratios in carbonates are made with an automated Europa Scientific Penta 20/20 isotope ratio mass spectrometer with CAPS preparation system. Determinations on prepared CO₂ can also be performed.

Waikato Mass Spectrometry Facility

The Waikato Mass Spectrometry Facility manages, operates and maintains the Faculty’s range of high-performance mass spectrometers. The instrumentation supports research and teaching activities within the Faculty and a range of services is available to external institutions and industrial clients. The facility is a Bruker Daltonics Centre of Excellence.

Waikato Radiocarbon Dating Laboratory

The Waikato laboratory is a national radiocarbon facility undertaking both Standard Radiometric Dating and Accelerator Mass Spectrometry Dating (AMS). The facility is an independent unit within the Faculty of Science & Engineering, and has been operating for more than 25 years. It is funded by external commercial customers and research grants, and is used to support radiocarbon dating and Faculty of Science & Engineering research programmes. Staff in the unit are actively involved in palaeoclimate and archaeological research and have a leading role in international calibration programmes.

Waikato DNA Sequencing Facility

The Waikato DNA Sequencing Facility (WDSF) offers DNA sequencing and genotyping services via capillary based DNA analysis systems. The WDSF provides sequencing and genetic profiling services for researchers from a wide variety of engineered, synthetic and environmental DNA templates using energy transfer and fluorescent chemistries.
Our Faculty has an international reputation for science and engineering research, assisted by some of the world’s most advanced laboratory equipment, and so our staff are well-placed to address new challenges.

We are happy to come to you and talk in more detail about your needs and opportunities, and how our work could contribute. If you are interested in meeting please contact one of the following:

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