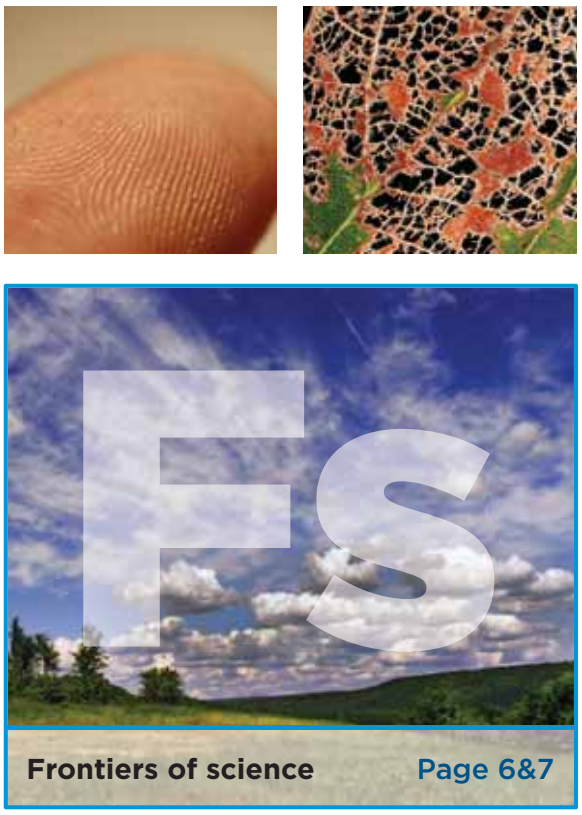
FACULTY FOCUS

A MONDAY MONTHLY SUPPLEMENT

FACULTY OF SCIENCE



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A WORD FROM THE DEAN

Professor Anton le Roex
Dean of Science

The Faculty of Science has a long and distinguished history. Formally established in 1918 by UCT's founding act, today it's a sizeable faculty of 12 departments and multiple research units, whose teaching and research is internationally acknowledged for excellence.

Colleagues of days gone by include two Nobel Prize winners (Aaron Klug and Allan Cormack, both from the Department of Physics), while today, some 40% of our academic staff are rated by the NRF as either international leaders (A-rated), having strong international reputations (B-rated), or being outstanding young researchers with the potential to become world leaders (P-rated). With over 800 research master's and PhD students, the faculty also contributes 25% of the publication output of the university and over a third of the university's annual PhD graduates. There is much to be proud of.

To maintain this high standard, and to increase our international visibility and impact, the faculty agreed earlier this year to focus its research energies on six broad impact areas that straddle the disciplines represented by the existing 12 departments. These impact areas are: African Climate and Development; Biodiversity and the Cape Floristic Region; Chemistry and Biology for Health in Africa; Marine Biology and the Southern Oceans; Southern Skies and the Evolving Universe; Human Evolution and the African Quaternary. These areas leverage our geographic advantage, while building on our established research strengths and critical mass. They also lend themselves to cross- and multi-disciplinary engagement – the watchwords of academic research and teaching today. You can read about each of them in the graphic below.

This strategic focus also informs the overarching theme for this *Monday Monthly* supplement focused on the sciences: the importance of understanding the world we live in, so that we can leave it an improved world for future generations.

While the stories you'll read in this supplement represent only a fraction of the research, teaching and learning that is going on in the faculty at any one point in time, I hope it inspires you – whether you're involved in the sciences or not – to make connections with and in the faculty; whether by engaging with students, teachers, and colleagues, or simply by considering new perspectives.

Further information about the faculty, its departments, research units and centres can be obtained from the website: www.science.uct.ac.za

SETTING THE SCIENCE AGENDA

Science's new research focus has six areas of strategic impact – making the most of the faculty's research strengths and critical mass, in conjunction with our geographic advantage.

African Climate & Development

Africa occupies a critical global position for the study of large-scale climate and environmental processes. Straddling the tropical, subtropical and temperate climate systems, as well as the Indian, Atlantic and Southern Oceans, the continent is influenced by a wide variety of atmospheric and oceanic circulation systems, including the dominant Agulhas and Benguela currents. These systems affect much on the African continent; its changing climate, its biota and human development. As a developing continent, our location also provides us with a clear advantage in terms of science and technology applications to social development in Africa.

Biodiversity & the Cape Floristic Region

The Greater Cape Floristic Region includes two Mediterranean biomes; fynbos (which includes renosterveld) and the succulent karoo. The succulent karoo biome is the world's greatest arid hotspot and the fynbos biome diversity competes with that of the Amazon forest. Besides encompassing an enormous amount of plant biodiversity, the region includes high levels of animal biodiversity, archaeological diversity and important perspectives on landscape development, climate change and earth history.

Chemistry & Biology for Health in Africa

The major global medical need of the 21st century will be in Africa, given the high disease burden and scale of the populations. The clinical expertise at UCT, coupled with the wide ethnic diversity of patients, makes the Western Cape a good environment to conduct translational science and medicinal research relevant to Africa, and the Faculty of Science is well placed to play a major role in this regard. The Western Cape is arguably the biotech hub of Africa – enjoying strong support from the Department of Science and Technology and strong links with the pharmaceutical industry.

FACULTY OF SCIENCE

Human Evolution & the African Quaternary

The western and southern seaboards have archaeological and palaeontological sites of world importance, which shed light on human evolution and the behaviour of early modern humans. Our geographic position, and our 'living laboratories' of local resources, provide the Faculty of Science with special opportunities, particularly in the earth and life sciences, to make important contributions to questions of global scientific importance and establish ourselves as international leaders in the field. Moreover, our location provides faculty researchers with ready access to southern-hemisphere climatic and environmental records over the timespan of the Quaternary. These records are urgently needed for integration into conceptual and computer-based models of hemispheric and global climate change, and will contribute to an improved understanding of earth system dynamics.

Southern Skies & the Evolving Universe

The astronomical landscape in South Africa has changed dramatically over the last decade. This is due to the construction of the largest optical telescope in the southern hemisphere (SALT), the Karoo Array Telescope (KAT-7), and MeerKAT (to be completed in 2016), and with the successful SKA bid for southern Africa (due for completion in 2022). Given our geographic advantage (with access to the southern skies); close proximity to the South African Astronomical Observatory; the SKA South Africa project office and MeerKAT remote operations headquarters; in addition to our strengths in observational astronomy, multi-wavelength radio astronomy, high-energy particle physics, gravity and cosmology, the Faculty of Science has an unparalleled opportunity to become an international leader in the study of the southern skies and the early universe.

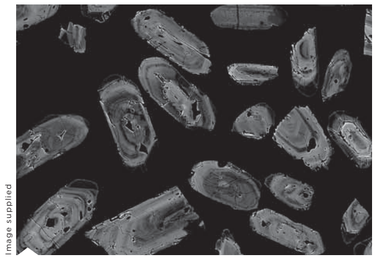
Marine Biology & the Southern Oceans

The marine environments around South Africa are among the most diverse anywhere in the world, and result from the meeting of the major Benguela and Agulhas currents associated with the South Atlantic and Indian Oceans, respectively, bounded to the south by the southern ocean. Furthermore, the interplay between these major currents and the southern ocean are central to African climate variability in the region, and diverse biology. The Faculty of Science has a long-standing international reputation for marine research, both biological and oceanographic, and is thus perfectly placed to be an international leader in this impact area.

BLINDED BY SCIENCE?

Curated by **Yusuf Omar**

UCT facilities that let you take a closer look at the world around you – whether you're peering into the depths of space and time, or studying the behaviour of subatomic particles in very cold conditions.



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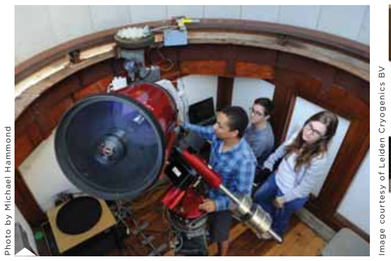

Photo by Michael Hammond

Image courtesy of Leiden Cryogenics BV

Electron microprobe

With an electron microprobe, you can study the chemical composition of tiny volumes of solids (from boron through to uranium), at the micron scale. [A single hair is 40 to 50 microns wide]. This device effectively shoots electrons at your sample, causing elements contained in it to emit X-rays that the microprobe diffracts through different crystals, and then measures.

At UCT it's often used to analyse kimberlite (a form of igneous rock in which diamonds are found), for elemental mapping (showing the distribution of elements in a sample), or for cathodoluminescence imaging of zircon grains (if you shoot electrons at luminescent materials, it can cause the emission of visible wavelengths. Zircon (seen in this image through an electron microprobe) is not only luminescent, but also incredibly durable, meaning it is contained in some of the oldest rocks on Earth.

UCT's JEOL Superprobe JXA-8100 Electron Probe Microanalyser facility is operated by Chief Scientific Officer Christel Tinguely and supervised by Dr Johann Diener.

Bolus Herbarium curator Terry Trinder-Smith. Photo by Je'nine May

Bolus Herbarium

UCT's Bolus Herbarium houses more than 350 000 specimens of dried plants, and is particularly noted for its broad representation of Cape flora. The third-largest herbarium in South Africa and the third-largest university herbarium in the southern hemisphere, the Bolus Herbarium is ideal for teaching students about the diversity of Southern African flora, and for researching individual specimens.

Housed in the Department of Biological Sciences, the herbarium facilitates research in various disciplines, such as taxonomy (scientific classification), systematics (the diversification of living forms), biogeography (the distribution of species across geographic space and time), endemism (specimens unique to a defined geographic region) and pollination biology.

It is also home to more than 14 500 type specimens (specimens used to describe a species for the first time) with representatives of the Cape flora forming the bulk – making it the most type-rich herbarium in South Africa. Each of the hundreds of thousands of specimens is kept safe in steel cabinets.

Optical telescope

It's not immediately visible to passers-by, but neither are the things it sees. The Department of Astronomy's new optical telescope is tucked away in the dome of the RW James building. Officially named the Tony Fairall Teaching Observatory in December 2013, the facility comes equipped with a new Celestron 14-inch telescope, as well as a charge-coupled device, which captures light more efficiently than photographic plates, and a spectrograph cap (a device that allows you to see and record the lines in a spectrum of light).

The Celestron's large 14-inch aperture gives stargazers a sharp view of the solar system under clear conditions, including all the features on the moon, detail in Jupiter's clouds and belts, and even a faint glimpse of Pluto. Weather permitting, astronomers can also feast their eyes on deep-sky objects such as nebulae and galaxies. The Department of Astronomy is compiling a 2015 calendar featuring images taken through the telescope.

The telescope is already being used to teach astronomical techniques to second-year students and optical photometry to third-year stellar astrophysics students.

The observatory runs under the direction of Professor Claude Carignan and Associate Professor Patrick Woudt.

Prof Anusuya Chinsamy-Turan inside the Palaebiology Laboratory. Photo by Je'nine May

Palaeobiology Laboratory

Bones might be all that's left of them, but that's just enough for UCT's Palaeobiology Laboratory to uncover some of the mysteries of vertebrates past.

Bones reflect a variety of events that affected an individual's life, including phylogeny (a species' historical evolution) and ontogeny (an individual's development from embryo to adult). By studying the microscopic structure of fossilised bones, scientists can gain insights into the biology of extinct animals.

But it's not just long-dead species that the lab studies. Reptiles, turtles, and a range of bird species are studied to provide a deeper understanding of factors that influence bone growth. These enrich the lab's core aim of shedding light on the lives and make-up of extinct animals, from flightless dinosaurs, to therapsids (mammals and mammal-like reptiles), parareptiles (a contested sub-class of ancient reptiles) and extinct elephants.

Dilution fridge

UCT's Physics Department will be home to the coldest place on the African continent when the department takes delivery of a dry dilution fridge in early 2015. This state-of-the-art instrument has a base temperature of 7mK, which is seven thousandths of a degree above absolute zero. At -273.15 degrees Celsius, absolute zero represents the lowest temperature possible – nothing can be colder, and an object at absolute zero retains no heat energy.

The cryogenic system uses a mixture of the isotopes helium-4 and helium-3 in combination with high-powered MagLev (magnetic levitation) turbo pumps to achieve its ultra-low temperatures and high cooling power. What kind of research can it be used for? Quantum cryptography (encoding messages using physics, not mathematics), transporting single electrons at a time, and the characterisation of nanocomposites (man-made materials built using nanoparticles), for example.

This facility will provide valuable training opportunities for students at all levels and allow UCT to become a player in a very active and exciting international field, says Professor Mark Blumenthal, the physicist who will oversee the use of the dry fridge.

Photo by Michael Hammond

Mantle Room

Thought to be the largest collection of its kind, the Mantle Room in the Department of Geological Sciences houses a collection of over 10 000 upper mantle-derived materials (mantle xenoliths and xenocrysts, kimberlites and related rocks, megacrysts, and deep-crustal xenoliths). These are used for research purposes, and collected mainly from South African diamond mines, including Jagersfontein, Finsch, Jwaneng and Kimberley.

A one-of-a-kind collection in terms of both the variety of specimens and range in locality, the Mantle Room includes samples from Russia to Brazil, assembled over the past 50 years, and is available to researchers from around the world.

Star trails over Sutherland

HOMEGROWN SCIENCE

Story by **Ambre Nicolson**

Why is it important for us to understand our local environment – our southern skies, southern oceans and all the flora and fauna in between? And what role should scientific study play in advancing this understanding?

S -33.955533, E 18.460527. These geographical co-ordinates pinpoint a very specific location: the PD Hahn Building, administrative home to some of the 12 departments that make up the UCT Faculty of Science. As precise degrees of longitude and latitude they describe a place balanced on the tip of a continent and poised between two major ocean currents. What they can't tell you is that this is a place surrounded by abundant and diverse animal and plant life and that it has been the site of scientific study for almost two centuries. In the past, as in the present, much of the work that has occurred here has been in the pursuit of a better understanding of this local environment.

Our place in the world

In a world beset by global challenges, however, is it myopic to be focusing on our own backyard?

"Science is universal," says Dean of the Faculty of Science Professor Anton le Roex. "So it's not about the value of African-centred scientific knowledge for its own sake, but rather the ways that knowledge of our local context can help advance global human understanding. By using our geographic location as an advantage we can ensure that we are the leading experts in specific fields. This in turn encourages the perception of Africa as a place of world-class science, and enables us to remain competitive as an educational institution."

So what makes our geographic location distinct in the eyes of science?

Our clear skies

If you have ever been in the Karoo on a cloudless night and looked up, you'll agree that South Africa has some of the clearest skies in the world. The altitude, climate and lack of light pollution lead to conditions that are not just good for amateur stargazing, but also for the kind that requires a radio telescope and seeks answers to how our universe began. In fact, one of the reasons that South Africa has been chosen to host the Square Kilometre Array (SKA) Project (which aims to create the world's largest radio telescope, with a collecting area of a million square metres) is the fact that we boast some of the clearest skies in the world.

According to Professor Renée Kraan-Korteweg, head of the Department of Astronomy, the development of the SKA project will have many positive side effects beyond attempting to answer questions about the cosmos. "SKA is not just exciting because of what it might achieve for pure science, but also for what it might mean for everyday life. As a flagship project, it requires the highest level of research infrastructure and computing power – this will certainly be an economic and technological driver and a means to create jobs. Just as important, it promotes South Africa as a scientific leader, encourages students to enter the field, and will continue to attract top scientific minds to our shores."

Our biodiversity

Professor Anusuya Chinsamy-Turan is a paleobiologist who "looks at how organisms change over deep time, across millions of years". She is also the first head of one of the faculty's youngest departments: biological sciences, created last year by combining the Departments of Botany and Zoology. "A central theme that binds our research is our unique geographical location, which we think of as a gateway to terrestrial biodiversity, as well as to the Southern and Antarctic Oceans," Chinsamy-Turan explains. "Our department's vision is to be recognised as a leading biodiversity research and teaching department, with strong inter-disciplinary research linkages that understand biodiversity resources in the face of climate change, both locally and globally."

In terms of her research, Chinsamy-Turan also points out that South Africa has the best record of the evolution and spread of mammal-like reptiles, as well as of the early ancestors of dinosaurs, mammals and modern reptiles. "We have a unique fossil record in South Africa, and we can track the evolutionary changes that happened among these creatures over the course of 120 million years through fossils. Everyone knows about our human fossil record in South Africa, but here in Africa we also have an incredible history of life on our planet."

Our record of human evolution

It is this record of human habitation and migration that interests archaeologist Professor Judith Sealy. "I do chemical analyses of materials found at archaeological sites in order to find out what ancient humans and animals were eating. This can tell us about the environment at the time they were alive, and their behaviour

South Africa has a much longer history of human habitation than elsewhere in the world, with many sites on both our coastlines showing the emergence of modern humans 200 000 years ago. "People often assume that this human habitation was quite static, but it was actually very dynamic. The study of these societies shows how our species emerged, and understanding more about this progression can tell us about our own physiology and psychology."

The diversity of our oceans

Every year more than 500 different species of fish and seafood are harvested from our waters – enough to provide adequate food for our local population, in Professor Colin Atwood's opinion. Atwood, who focuses on wild fishing (as opposed to marine aquaculture), explains that in some cases we have overfished certain species; but that others, such as hake, show increasing population numbers. "The real problem comes with governance. How can we ensure the proper regulation of our fishing industry in a way that protects our natural environment while supporting the livelihoods of smaller fishers?"

Two major currents so close to each other, the cold Benguela Current along the west coast of South Africa and the warm Agulhas Current off the east coast, together with the vast Southern Ocean further south, mean that South Africa occupies a unique oceanographic position. Professor Chris Reason explains that "studying the Agulhas Current and the Southern Ocean is extremely important because of the key role they play in global climate and change."

Our problems

Some of the problems we face as a country, and as a continent, are specific to the developing world, and many other global concerns still have specific consequences when viewed in the context of our status as a developing nation and region. One such example is climate change.

Dr Gina Ziervogel, who studies social and environmental adaptation to climate change, claims that while the steps required to mitigate or adapt to climate change are often seen as being incompatible with development, this is not the case. "Take for example the case of policymakers in Durban who did not support taking steps to adapt to the consequences of climate change in the future. When unseasonal storms disrupted the roll-out of low-cost housing and services to urban areas, they began to see climate change not only as an environmental issue but also as a social one. As scientists we have a responsibility to ensure that these issues get on the agenda."

Human health is another area where our geographic location makes particular diseases relevant. Professor Ed Rybicki from the Biopharming Research Unit in the Department of Molecular and Cellular Biology works on developing new ways of making vaccines for some of our region's most pressing diseases, such as HIV and HPV [the human papillomavirus, which causes cervical cancer]. In his words: "Diseases like HPV, HIV and the rotavirus, which causes diarrhoea in babies, affect people disproportionally in developing countries. I do think we have a responsibility to try and find solutions, especially at an institution such as UCT, which is capable of such sophisticated science."

Local problems, local solutions

South Africa remains the country with the highest incidence of those living with HIV in the world, and the enormous cost of the disease, both human and economic, is felt most keenly here. In cases such as this, local science can have an important role to play in creating homegrown solutions.

"Such problems also encourage a multidisciplinary approach, and I believe this is something which has emerged naturally throughout the faculty," says Le Roex.

Professor Janet Hapgood, from the Department of Molecular and Cellular Biology, researches what form of contraceptives best suit women at risk of contracting HIV. She cautions that while great strides have been made, many challenges to collaboration still exist. "I believe that we must create better incentives and forums to facilitate interdisciplinary partnerships, particularly between faculties and different institutions."

Dr Miguel Lacerda uses statistical models to identify regions in the HIV genome that are important for vaccine design. His work, he says, would not be possible without collaboration between very different kinds of scientists. "The virologists I work with have experimental methods for identifying these regions, but they are expensive and time-consuming. Working together, we can develop and validate predictive models that will save time and money."

Encouraging interdisciplinary approaches at UCT is Professor Robert Morrell's job. He has been tasked with, among other things, promoting African collaboration through the Programme for the Enhancement of Research Capacity. "When we acknowledge that there are different ways of knowing, we have the opportunity of using a variety of approaches and methodologies. This broadens horizons and allows for new questions, the possibility of different answers, and better remedies for sickness. The challenge is to find ways of promoting dialogue between different approaches, and of melding local knowledge with scientific method. The old idea that science presents fixed, immutable facts is changing; and as it does, the realm of possibility is becoming greater."

Associate Professor Merle Sowman from the Department of Environmental and Geographical Sciences believes that in order to achieve authentic homegrown solutions, the role of local knowledge must also be recognised. "I work with coastal fishing communities and some of my work is about understanding different ways of knowing about the same ecological context, and how we can co-produce useful knowledge in partnership with local communities. I think it is very important that we open ourselves up to understanding the different values and cosmology that local communities may have, especially in a country such as ours, with such a pluralistic legal environment, where up to 50% of people follow customary law. Ideally we should be collaborating together with these communities to set the research agenda."

Proudly African science

Do local scientists have a responsibility to help raise the profile of science on the continent? Professor Bruce Hewitson believes so. As a climatologist he believes it is essential that African scientists educate the international community about our knowledge needs. "We must reverse the process as it has so often happened before, by making sure that African science leads the Africa agenda, rather than simply responding to the priorities set from elsewhere in the world."

To raise the profile of African science is also to invest in students themselves, both to encourage students from diverse demographics to enter the field and also by giving them the opportunity to learn here and then import that knowledge back into their own local contexts. "Something that is very exciting about the current interest in our work, " says Kraan-Korteweg, "is the fact that many students from across the continent now have the opportunity to be at the forefront of astronomy here at UCT, and then to take that knowledge back to their home country."

For the sake of future generations

The principle of intergenerational equity is the idea that we have an obligation to preserve our natural environment and resources for future generations. To do so, we must rely at least in part on scientific knowledge to understand, conserve and protect our biodiversity for the future. Science, as Chinsamy-Turan points out, can give us a sense of perspective: "What is a year or a decade in the scale of geological time? Looking at the past can tell us about the present; but it can also highlight the fragility of life on our planet, because even small changes, over time, can lead to catastrophic events."

The question of how we can best go about being responsible stewards, so that our children's children will still be born into an environment teeming with diversity and abundance, is one that science is well placed to answer.

GROWING YOUNG SCIENTISTS

Compiled by **Yusuf Omar**

UCT's top scientists are recognised globally for their work, but Associate Professor David Gammon recognises that grooming the next generation is just as important to keeping the Faculty of Science in shape.

For the second year running, the assistant dean has spent a week in July sharing the wealth of UCT's scientific research with first-year students, equipping and inspiring them for the semester ahead.

Some 50 students discussed the physics of optical phenomena such as sun halos – often seen around Cape Town – with mathematician Dr Jonathan Stock, and explored whether science could save lives with Dr Wendy Burger, with reference to her own work on HIV and TB.

This was among a range of other lectures and excursions, including a visit to the West Coast Fossil Park at Langebaan to see the active Stone Age dig and fossil evidence of bears and short-necked giraffes near Cape Town. The students' interest in oceanography was piqued by spending a morning on board *Agulhas II*, South Africa's research ship, with UCT oceanographer Dr Isabelle Ansorge and her colleagues.

Between all this, students were given a head start on scientific concepts that they would encounter in the first two weeks of the new semester, and also took part in a session on 'thinking about thinking', and how to re-evaluate their approach to their own studies.

Gammon says that the winter school targets some interconnected challenges that are common to the first-year experience in the faculty. These include the fact that students often have limited knowledge or experience of the range of options open to them, and have encountered relatively few role-models of working scientists; and that they consequently struggle to find inspiration and motivation in their studies – which adds to the challenges they already face in coping with demanding subjects, says Gammon.

"So the idea was to put together an interesting and inspiring programme, drawing on the wealth of expertise in the Faculty of Science and the range of scientifically interesting projects and initiatives both at UCT and in the greater Cape Town region," Gammon says.

One student said of the winter school: "I sense a shift in my confidence; and more importantly, an increasing passion for science."

Another reported that the winter school "has made me feel less helpless and alone by showing me that other people just like me are experiencing the same conflicts I am. It has sharpened my resolve to improve this semester, and to actually get gritty and work hard".

Aspirant scientists at UCT Open Day. Photos by Michael Hammond and Raymond Botha.

This photo, looking across the southwestern tip of South Africa, was taken from the International Space Station on 9 May 2013 by Canadian astronaut Chris Hadfield. Writing in *Wired*, Hadfield said: "While I was on the space station, I used Twitter to ask hundreds of thousands of people what they would like me to take a picture of. Resoundingly, the answer was 'home'. After millennia of wandering and settling, we are still most curious about how we fit in and how our community looks in the context of the rest of the world." Image courtesy of NASA/JSC

NEW FRONTIERS, NEW ADVENTURES

"Discoveries in science ... will continue to create a thousand new frontiers for those who would still adventure," said former US president Herbert Clark Hoover. Helen Swingler asked a handful of UCT researchers to speak about their adventures at the outer limits of science.

The debate is over
Climate scientist Professor Mark New

"The debate about whether greenhouse emissions cause climate system warming is over. Frontiers of knowledge in the physical and natural sciences now concern how different aspects of the climate system will respond to overall warming. At the most fundamental level, there is still a lot to understand about feedbacks in the climate system – those internal responses that can act to amplify or dampen the direct greenhouse gas effect.

"In the Southern African context, we have a critical role to play in southern hemisphere climate change research. With regards to carbon cycling, the southern ocean is a key player in ocean carbon cycling, and is very poorly understood. Also, we do not have a good understanding of how carbon cycling in African grasslands and forest biomes will respond to climate change.

"There are also a number of critical research challenges and questions around adaptation. First, the development of methods and techniques that enable the interpretation and development of response strategies that embrace uncertainty; and of course, training practitioners and policymakers to be comfortable with planning for a more climate-resilient society as part of an overall sustainable-development agenda.

"Second, and related, is the need for integration. Climate will impact on society as a whole, so the classical reductionist approach in science, while useful for building basic understanding of components of a system, does not address the complexities of the real-world systems, whether these are cities, food systems, or ecosystems in the larger social-ecological systems we are part of; and in particular, the political-economic realities of responding to climate change.

"We need new paradigms of thinking, drawing on – among others – complexity science and transdisciplinary methodologies. We need to bring together expertise from both the natural and physical sciences, with other disciplines such as law, economics, humanities, health, on an equal footing."

The emergence of complexity
Cosmologist and Distinguished Emeritus Professor George Ellis

"Key questions for today's cosmology are the nature of dark energy and the nature of dark matter. The nature of dark energy, and particularly why it is so small, is still a mystery.

"There are also many other key areas where new theory and observations are needed to probe the nature of fundamental physics. One example is that we still don't understand the foundations of quantum physics, even though we understand a great deal of how it works.

"There are really great experiments taking place in this regard. This might have repercussions for many questions in physics, cosmology, and even biology – where a key issue is what (if any) genuinely quantum effects influence biology in general, and the brain in particular. For me, that kind of issue – a deeper understanding of the emergence of complexity from the underlying physics and chemistry – is one of the most exciting areas of all.

"We need to do both blue-sky research and research directed at areas of critical need, such as the coming water crisis. The whole point of blue-sky research is that what will come out in genuine discovery is often quite unexpected – for example the nature of quantum theory, of the genetic code, of the way the brain is structured. This can then lead to major important new applications, such as the existence of transistors and lasers.

"However, research into areas of critical need is essential; indeed, it is our duty to society to work on these areas too – for example, climate change and energy issues on the one hand, and poverty on the other.

"A particular critical area is education. Our educational success or failure relates to how we understand learning processes in the brain. There are some high-profile neuroscientists out there with reductionist views who are advocating for disastrously low-level educational methods. Tackling this area should be a high priority for quality interdisciplinary research that takes a deeply human view as well as being fully aware of the latest scientific understandings of brain structure and function."

Under the sea
Marine taxonomist Professor Charles Griffiths

"Some frontiers are tantalisingly close; a mere 1 000m under the ocean. We're describing some 30 new marine species a year in South Africa; and many of these are 'on our doorstep' in False Bay, as that's where most of our sampling is done. If we could get deep-sea samples, the majority of the species would be new, but we lack the capacity to collect these samples.

"So, the frontier regarding biodiversity is certainly the deep sea, which is extremely poorly explored. I'd want to get my hands on samples from the 70% of South Africa's exclusive economic zone that lies deeper than 1 000m.

"Continental South Africa has a coastline of some 3 650km, and the EEZ is over one million square kilometres. Waters here are as deep as 5 700m, with more than 65% deeper than 2 000m. Although the coastal zone is quite well sampled, most samples were collected before 1980. And over 99% of existing samples are from depths shallower than 1 000m – in fact, 83% are from less than 100m. The abyssal zone thus remains almost completely unexplored.

"Yes, there are vessels that can take samples, and a handful of submersibles that can physically take researchers down to those depths, but they cost tens of thousands of dollars a day, and we have not been able to raise that type of funding."

Currents of change
Oceanographer Professor Frank Shillington

"Climate change has affected both the scope and the urgency of particular aspects of the various branches of oceanographic research. Firstly, it's impressed on us the need for longer and more comprehensive observations of the ocean, particularly around the southern tip of Africa.

"As researchers, one of the limits on our detailed knowledge of how the physical processes of the ocean behave is not having a comprehensive and detailed observing system. As this has steadily improved, along with the capability to numerically model the coupled ocean-atmosphere system, our knowledge will continue to increase.

"The next big frontier will be to sample the ocean at what are called 'sub-meso' scales, of between one and 10 kilometres.

"Within our context at the tip of Africa, the big unknown is how the great Agulhas Current, sweeping hundreds of tonnes of warm water down the east coast of South Africa towards Port Elizabeth and beyond, will change under changing wind conditions in the Indian Ocean.

"About 80% of this huge current does a U-turn on itself and re-circulates back into the Indian Ocean, but the important remaining part travels into the Atlantic Ocean, supplying both heat and salt to the northern Atlantic Ocean, and thus helping to complete the circuit of the Great Ocean Conveyor, or Meridional Overturning Circulation (MOC).

"How this southern surface part of the MOC may change in response to changing wind forcing is being studied through the deployment of a deep-reaching array of moored ocean buoys from Cape Town to South America, as well as by satellite remote sensing by different radar instruments.

"With the increasing availability of large data sets from satellites, and vast quantities of suitable numerical ocean model output, it is envisaged that big data and its visualisation, analysis and presentation will eventually be required."

Physics: the game changer
Particle physicist Dr Andrew Hamilton

"The discovery of the Higgs boson in 2012 was very big news and completed our understanding of the standard model of particle physics, our current best understanding of the fundamental nature of energy, matter, and force in the context of what is called quantum field theory.

"In many ways it was the missing piece that completed the puzzle. Unfortunately, the finished puzzle still does not give us a complete understanding of the universe – there are other puzzles out there! In my opinion, the largest question in physics (post-Higgs boson discovery) is the unification of gravity with quantum field theory.

"Is there one thing that underpins and connects our understanding of all three? Answering the quantum gravity question may lead to the nature of dark matter, dark energy and black holes.

"This will not change the way we think about rain, or ice cream, or emails, but if it were not for CERN researchers we might be thinking about emails in a very different way. Do you every wonder why an SMS costs 50 cents, but an email is free? Part of the answer is thanks to particle physics researchers at CERN."

[Hamilton points to a CERN link, which describes the birth of the World Wide Web – developed in 1989 by Tim Berners-Lee, initially to meet the demand for information-sharing between physicists at universities and institutes around the world. Twenty years ago CERN published a statement that made the World Wide Web technology available on a royalty-free basis. And so the web flourished, and transformed the world and the way we communicate, innovate, work and live.]

"Today's technology depends on fundamental physics: the GPS in your phone depends on general relativity, your computer depends on quantum mechanics. Without a clear understanding about the way in which the laws of physics work, we cannot use the laws of physics to build technology that helps our everyday life."

New uses for old drugs
Organic chemist Professor Kelly Chibale

"One of the exciting areas in drug discovery is the exploitation of genome information within the context of drug repurposing and repositioning – the investigation of existing drugs as potential therapies for other diseases.

"Whereas these two terms have been used interchangeably by some, drug repurposing specifically refers to cases in which an existing drug, approved by a regulatory agency in one disease area, is found to have activity against another disease.

"Drug repositioning describes a situation in which a drug active in one disease is 'derivatised', or used as a template for the synthesis of derivatives active in another disease.

"The concept can also be extended to new uses for drugs that have failed for one indication, either pre- or post-approval, or have been abandoned in development, in which case the term 'drug rescue' is used.

"These approaches can significantly shorten the drug discovery process, as in most cases the candidates will have been through several stages of clinical development and will have well-known pharmacokinetic and safety profiles.

"One of the many scientifically rational approaches to repurposing and/or repositioning is the exploitation of genome information. This involves the exploitation of known biological targets in one disease for the development of drugs in other diseases with homologous targets. This has sometimes been referred to as 'target repurposing'."

Computer-aided design
Computational chemist Professor Kevin Naidoo

"The computational revolution has changed the way we do science. In every scientific discipline, the frontier lies in the progression of computation, from an adjunct to an essential part of our understanding nature. The cusp of progressive knowledge acquisition is in the reformulation of the scientific method. This relies on the production of computer models that are verifiable and able to predict the outcomes of experiments, and so provide a view into nature that's not accessible from microscopes, telescopes or spectrometers.

"We tend to believe what we can see and touch. Yet in many fields, such as chemistry, our knowledge is deliberately biased by what we indirectly measure with physical instruments.

"I say 'indirectly' because experimentalists often forget that the raw feed of light and sound wavelengths coming from their detectors has been washed through a theoretical model to produce what are considered unshakable results pulsing from the printer next to the machine.

"We must acknowledge that the bias lies in the model sitting between the detector and the scientist. In chemistry, for example, it is ironic that the very essence of this science relies on a model interpretation of things we cannot see, such as electrons and bonds between atoms.

"Reproducibility and prediction are the enviable achievements of the scientific method. Computational scientists increasingly provide predictable computational models of electrons, atoms and molecules that can be used to design materials and pharmaceuticals, and interpret the interwoven chemistry of cells to connect to the chemical events that have long passed in galaxies light years away.

"Computer models and data analytics provide a rational approach to discovery that is in contrast to traditional trial-and-error searching. This rational approach to chemistry and biology promises to address burning problems such as the development of biomarkers for early detection of cancer, drug resistance, and making bottomless barrels of biofuels from cellulose (the most abundant molecules in the biomass)."

> "We tend to believe what we can see and touch. Yet in many fields, such as chemistry, our knowledge is deliberately biased by what we indirectly measure with physical instruments."
>
> **Prof Kevin Naidoo**

WHAT'S IN A NAME?

Compiled by **Yusuf Omar**

The scientific method might be stringent, but the methods for naming can often be weird and wonderful.

This frilled nudibranch, *Leminda millecra*, is named after Prof Charles Griffiths' daughter, Melinda. Image by Georgina Jones.

Take quarks, for example. Rather than being given a name derived from ancient Latin concepts, the subatomic particles derive their names from James Joyce's *Finnegans Wake*, which reads:

Three quarks for Muster Mark!
Sure he has not got much of a bark
And sure any he has it's beside his mark.

While Joyce's "quark" rhymed with "mark", physicist Murray Gell-Mann coined the term 'quark' – as in 'cork' – because protons and neutrons each contain three of them. The names of the six types of quarks might also raise an eyebrow: up, down, charm, strange, top and bottom.

Golden moles

Dr Gary Bronner is a more visible example of a somewhat liberal scientific naming process. The UCT zoologist was "rather bemused" to have had a five-million-year-old fossil mole named after him in 2010. *Chrysochloris bronneri* was a golden mole that burrowed under the soils of the Western and Northern Cape many ice ages ago. It is closely related to the living Cape golden mole, *Chrysochloris asiatica*, which is common in the South-Western Cape and Northern Cape coastal plain.

Bronner was a member of the research team that was deriving a phylogeny (evolutionary tree) from the then-poorly-studied *Chrysochloris* family, comprising 21 golden mole species.

Maroon orchids and minerals

When it burrows up towards the surface, the golden mole might bump the roots of *Disa linderiana*, an orchid species named after former UCT professor Peter Linder. The maroon orchid was spotted by CapeNature field ranger Jacques van Rooi in 2004, in the Cederberg.

Ducking back below terra firma – but much deeper than your average mole could hope to dig – one finds a mineral called Mathiasite. This potassic iron-zirconium-magnesium chromian titanate is named after the late, legendary UCT geologist Morna Mathias.

The mineral was described in a 1983 paper by Steve Haggerty of the University of Massachusetts, Amherst, and others, in honour of Mathias' seminal studies on alkaline rocks and her early contribution to the mineralogy, petrology and geochemistry of mantle-derived eclogites and peridotites.

Mathiasite is found in the earth's deep mantle, more than 100km below Southern Africa.

Shrimps and sea slugs

Sticking to the depths but moving under water, a genus of freshwater shrimp endemic to the Knysna area has the unique honour of being named after Professor Charles Griffiths' son, Matthew, whose request for a loo stop during a family holiday in the area led to his father noticing these animals in a roadside stream! The shrimp, named Mathamelita, was described by Griffiths and a colleague in 1995.

The Griffiths family was also involved with the naming of a new family of sea slugs – former UCT scientist Dr Roberta Griffiths (wife of Charles) named the colourful sea slug *Lemindidae* after their daughter Melinda (herself a recent PhD graduate from UCT).

Bat brothers

Associate Professor David Jacobs also decided to keep it in the family when he named a new bat species in 2009. Jacobs and his students came upon the yellow-bellied bat in the iSimangaliso Wetland Park in KwaZulu-Natal in 2003. It was startlingly similar to its sympatric sibling, *Scotophilus dingani*, a bat named after the Zulu king Dingane. So Jacobs decided to name the new addition *Scotophilus mhlanganii*, after Dingane's half-brother, Mhlangani.

MSc students venture into a wasteland created by open-cast pit diamond mining along the Namaqualand coastline. They are part of the Namaqualand Restoration Initiative, a community-focused project to rehabilitate this fragile ecosystem. Image by Carina Bester.

SCIENCE ON THE GROUND

Story by **Helen Swingler**

The interface between community and science is a complex interaction best described as a relationship of reciprocity. From smallholders and artisanal fishers to bundu-bashing citizen scientists, communities are making their mark on science – and both are benefiting.

Upside down and turned around
Ecologist Dr Peter Carrick

Along the 400km coast of Namaqualand, diamond mines have turned the fragile ecosystem upside down. Literally. Designated as one of the world's 43 biodiversity hotspots, this zone is the most species-rich arid environment in the world. Many species are habitat specialists.

It's ironic that jewels other than endemic bulbs and mesembryanthemaceae are also found here – in rich seams just 50 metres or less under ground. Open-cast mining has overturned thousands of hectares in discontinuous patches, leaving holes and dumps of overburden that have all but destroyed locals' livelihoods.

Legislation now requires mining companies to clean up, restoring the landscape during and after mining operations.

That's where the Plant Conservation Unit's Dr Peter Carrick comes in, with the Namaqualand Restoration Initiative (NRI), launched in 2005 as part of the Succulent Karoo Ecosystem Programme.

This initiative tapped into Namaqualanders' deep knowledge of the land to equip teams from local communities to rebuild the ecosystem. The NRI did a 'sweep' of local and scientific knowledge from farmers, mine operators, agricultural scientists, and local naturalists and herders (often with few resources but great insight), to synthesise their working knowledge of restoration techniques.

Local teams operate as formal businesses and contract to mining operators, gaining access to the formal economy and negotiating their terms; and with them, increasingly, their future. The service they offer has been scientifically developed and is a tried-and-tested system involving 'restoration packs', wind-erosion barriers and transplants to restore former mining sites. The NRI is also able to provide assurance to mining operators that the system has been implemented correctly.

An offshoot of NRI, NM Restoration, is now a business owned and run by Namaqualanders.

Carrick, who won an NSTF-BHP Billiton award in 2012 for this work, has since established Nurture Restore Innovate, an initiative that provides long-term ecological advice, support and mentoring to projects that affect landscapes on a larger scale.

"This extends the work of the Namaqualand Restoration Initiative, both geographically and by creating systems to implement the restoration at scale."

The new NRI has recently completed the first phase of research with mining operators on the arid edge of the Kalahari in Namibia. This creates comprehensive restoration systems for the land degraded by mining in this area, principally turning massive overburden and waste rock dumps into hills that look and function like those found naturally in that landscape.

This work has been done in partnership with MSc students and researchers from the University of Namibia.

In Namaqualand the new NRI has now broadened its restoration research to the koppies and uplands that have been degraded by centuries of ploughing and constant grazing.

Research is being done into restoration systems for these rangelands that can be rolled out as part of government's Expanded Public Works Programme, or what could be called 'Working for Ecology' or 'Working on Rangelands' programmes, says Carrick.

"This all works to alleviate poverty in the short term by creating pro-poor work opportunities, and in the long term by restoring productivity to dry, degraded rangelands, so that people can earn more productive and sustainable livelihoods from the land."

Citizen power in numbers
Biologist Dr Sally Hofmeyr

Citizen scientists in the veld, plains, bush and mountains play a small but invaluable role in the scientific endeavour. These are ordinary people who enjoy documenting the natural world, their collective data guiding researchers like the Animal Demography Unit's (ADU) Postdoctoral Research Fellow Dr Sally Hofmeyr.

Hofmeyr has been studying secretary birds (*Sagittarius serpentarius*), large, terrestrial birds of prey endemic to Africa and usually found in the open grasslands and savannah of the sub-Saharan region. Using data from her first postdoctoral study in 2012/2013, she published a paper in *PLOS ONE* (a scientific journal put out by the Public Library of Science), co-authored with the ADU's director, Emeritus Professor Les Underhill, and Wits University's Dr Craig Symes.

It pointed to an alarming trend.

"This interesting and iconic species appears to be declining in the country – most severely, apparently, in the Kruger National Park, usually thought to be a haven for large raptors," says Hofmeyr.

The researchers were able to identify this trend using data citizen scientists had contributed to the Southern African Bird Atlas Project and the Co-ordinated Avifaunal Roadcounts.

"Long-term public participation or citizen science projects make it possible for observations made by many different people to be pooled and analysed as a whole," the authors explain in their introduction. "They provide the best opportunity for assessing population trends in species such as the secretary bird."

The relationship of reciprocity is reflected in the fact that the team chose to publish their paper in *PLOS ONE*, an open-access journal: "Since the data we used was contributed freely by citizen scientists, and freely available to them as well, it made sense to publish in a way that allows anyone access to the article," says Hofmeyr.

Seed knowledge
Environmental scientist Associate Professor Rachel Wynberg

In environmental and geographical science, National Research Foundation Bioeconomy Research Chair Associate Professor Rachel Wynberg is thinking about seeds.

The Seeds and Knowledge Initiative works with farmers, NGOs, researchers and policymakers to revive and enhance traditional seed and knowledge systems, while also deepening scientists' understanding of their functioning in the context of agricultural, cultural and ecological practices.

"We want to build a community of practice around seeds and knowledge in the region," says Wynberg, who is one of the organisation's partners, itself a long-term collaboration with Biowatch South Africa and the Mupo Foundation.

Local agricultural systems have been eroded for decades by policies and laws that promote the interests of commercial farmers and multinational seed and agro-chemical companies. Traditional seed varieties have all but disappeared in many areas, along with the associated knowledge and culture.

"Industrial agriculture produces only 30% of the world's food," notes Wynberg, "but it's a leading contributor to climate change and environmental degradation through destructive farming practices, use of fossil fuels and reliance on chemical inputs."

The long-term vision is to collaborate with communities, and national and regional partners, so that smallholder farmers – women in particular – have more control over seed procurement and food production.

"The first priority of the project is to help communities and farmers revive traditional seed and agricultural knowledge systems," says Wynberg. "Farmer exchanges have fostered horizontal learning and knowledge exchanges between communities, and across the region's borders. Learning exchanges are also taking place between researchers involved in formal seed systems such as gene banks and custodians of farmer-led systems."

Ongoing research, documentation, and experiential learning are vital to shifting the paradigms governing policymaking in science, she says.

"Traditional knowledge and seed and agricultural systems are part of a complex socio-ecological system in farming communities throughout Southern Africa. We want to bridge the gap between community realities and policies, and to support this process with research that has a social impact."

Seeds and Knowledge gives smallholder farmers, particularly women, more control over seed procurement and food production, and harnesses community knowledge.

Peace parks
Human geographer Associate Professor Maano Ramutsindela

'Community' is a watchword for human geographer Associate Professor Maano Ramutsindela, whose work on peace parks examines the movement of human and animal communities.

Peace parks – such as the Kgalagadi Transfrontier Park, which straddles the border between South Africa and Botswana – link conservation areas and ecological and cultural footprints. They're meant to promote local community development, biodiversity conservation and regional integration.

"They're founded on the philosophy of co-existence among humans and between humans and nature," Ramutsindela explains. "Regionally they're an avenue for integration; for example, Southern African states united by a common vision and managing their shared natural resources together."

Peace parks have increased the habitat for species such as elephants and have brought some areas with critical biodiversity under protection. But they have also metamorphosed, from the initial idea of bringing together a mosaic of land under various forms of tenure into a common conservation entity, to that of a park or wilderness with its consequent separation between humans and nature.

"What was supposed to be a progressive multi-land-use transfrontier conservation area is becoming an exclusive transnational park that allows free movement of wildlife and tourists, while ensuring that the movement of ordinary local residents is restricted," says Ramutsindela.

What's happening to the land – and other resources – that residents living near these conservation areas relied on?

"The answer is 'green grabbing'; the appropriation of land and resources for environmental conservation and the greening of the planet. In the context of peace parks, this process enlarges the conservation areas through colonial-era removals, the creation of wildlife management areas, co-management of land, and outright purchase of land in private hands."

Research, Ramutsindela says, is vital to assess and monitor the environmental and social outcomes of these processes in the parks. The irony, he notes, is that local communities, whose land rights are often precarious, are not involved in the planning of these parks.

"Issues of human rights should be central to the planning and establishment of peace parks."

Sea change in community education
Marine ecologist Professor Astrid Jarre

For the Marine Research Institute's (MA-RE) Professor Astrid Jarre, natural and human social systems are at the heart of a transdisciplinary project on coping with global change in the Benguela Current large marine ecosystem, which extends along South Africa's west coast and south coast, approximately to East London. Researchers are hoping to create knowledge that will help coastal communities tackle many of the problems they're facing.

The South African Research Chair in Marine Ecology and Fisheries, Jarre says that collaboration between researchers from various home disciplines (from the natural and social sciences) and including citizens, is generating transdisciplinary approaches that are distinctive in research progress and outcome.

One such project is a citizen-in-science approach to the colony of endangered African penguins at Stony Point, Betty's Bay.

"As human contact needs to be carefully managed, citizen scientists can't be involved in direct contact-based penguin research," says Jarre. "But drawing on sociological and anthropological techniques, our research has shown that Betty's Bay residents show overwhelming support for a well-managed penguin colony, even though this will increase vehicle and tourist traffic. The planned interpretative centre has huge potential to evolve as a true collaboration among the residents, and with the managing authority."

The Southern Cape Interdisciplinary Fisheries Research (SCIFR) project is another example of research involving citizens: "Fishers, learners and academic researchers are now involved, through SCIFR, on a collaborative process to improve our understanding of long-term change on the Agulhas Bank, south of Cape Agulhas."

Tangible results have resulted from collaborations; one is a seawater sampler, co-designed with local fishers, that is deployed from commercial ski boats: "The incoming data on temperature at the sea surface and at fishing depth are quality-assured by researchers, and further processed by learners in coastal schools in the Hessequa municipality in the Eden District," says Jarre.

"We envisage that communication on climate-related questions, which will involve all three groups, will enhance scientific research, and community understanding of the scientific process – as well as long-term change."

SCIENCE IN THE ARCHIVES

Curated by **Renate Meyer**
Compiled by **Helen Swingler**
Photos by **Michael Hammond**

Among the university's special collections are numerous scientific archives: papers, notebooks, photographs and plates that document – mostly by hand – scientific endeavour and discovery in an earlier age, before computers, cameras and colour printing.

A reproduction of Prof JLB Smith's famous coelacanth leaflet (offering a reward for specimens of the prehistoric fish), republished in his 1956 book, *Old Fourlegs: The story of the coelacanth*.

A hand-coloured print of *Disa spathulata* belonging to UCT's Bolus Herbarium.

A spore pressing of a scaly psalliota, a mushroom found at Brakkloof on the Cape Peninsula, and a notebook listing the peninsula's poisonous, edible, eatable, non-edible and unknown fungi, made by botanist Edith Stephens.

This photograph by Edmund Schelpe – the former curator of the Bolus Herbarium and professor of plant taxonomy in the Department of Botany – is of entomologist John Riley next to a giant lobelia, taken during an expedition to Mount Kenya in 1949.

Astronomer Dr Andrew David Thackeray's detailed plottings of the variances of star clusters.

One of four large mounted drawings of the Royal Observatory in Cape Town (now the South African Astronomical Observatory) from the papers of Jacob and Eric Halm.

THE BIG DATA REVOLUTION

Story by **Tracy Gilpin, Carolyn Newton and Jane Notten**

Big data – large and complex data sets that are difficult to process using traditional computational hardware and software – is a popular term that has gained ground in the last decade, not only in everyday life, but also in research. UCT is taking the lead in creating the framework to allow African researchers to get to grips with the increasing volume, velocity and variety of data, and turn it into actionable knowledge.

Construction of the MeerKAT antenna. Image courtesy of SKA South Africa

The modern world is experiencing a data deluge: "The data flow is so fast that the total accumulation of the past two years – a zelabyte – dwarfs the prior record of human civilisation," wrote *Harvard Magazine* in March 2014. No-one is immune – least of all researchers, who now work with large data sets that are increasing exponentially in size, complexity and velocity. While data-intensive research cuts across the disciplines – including engineering, computer science, archival science, humanities, economics and finance – the sciences frequently find themselves at the frontier of attempting to solve big data problems.

In 2001, Gartner Inc, a leading information and technology research and advisory company, defined big data as: "High-volume, -velocity and -variety information assets that require cost-effective, innovative forms of information processing for enhanced insight and decision-making."

The more data available, the bigger the potential for more accurate analyses. And with more accurate information available, decisions can be made with increasing confidence, while better decision-making leads to greater efficiencies, cost reductions and reduced risks across societies.

But this will only happen if the capacity exists to interpret that data correctly. Getting from data to knowledge is not a simple equation, and the need to support data-intensive research at universities is therefore acute. Increasingly, researchers are battling to move data sets between collaborator sites, test parameters to optimise analysis of large data sets, and faciliate access to these sets by international research communities. In the last 12 months, UCT researchers have more than doubled their use of central high-performance computer (HPC) facilities for data-intensive research. Demand for research storage is growing substantially each year, and specialist support and analysts are in constant demand.

"Without the right support, UCT researchers risk diverting time and resources into the development and maintenance of potentially sub-standard or inefficient solutions, or just generally taking much more time to do meaningful analysis," says Professor Danie Visser, deputy vice-chancellor with responsibility for research. "There is increased potential for valuable data or intellectual property to be lost, stolen or corrupted, and for significant interruptions to research activity. A centralised effort is needed to provide a mechanism for researchers to learn from one another and develop institutional best practice."

It is partly for this reason that UCT is establishing an eResearch Centre. eResearch is focused on how information and communications technologies help researchers to collect, process, store, manage, find, share and re-use information. In line with moves at other leading international research institutions, the centre will provide integrated support to help researchers do work that is high-impact, locally relevant and internationally competitive. One of its important roles will be in managing large data sets.

The university could go further, however, building on the eResearch Centre to take the intellectual lead in establishing expertise and driving innovation in data science. There are a number of global and national developments that the university can harness.

An accelerating challenge

One such opportunity lies with the European Organisation for Nuclear Research (CERN), home of the Large Hadron Collider (LHC), says Dr Andrew Hamilton, a lecturer in the Department of Physics and researcher in high-energy particle physics at CERN. The 27-kilometre LHC is the world's largest particle accelerator, and it is one of the most important tools available to high-energy physicists in their bid to investigate the fundamental particles that make up the universe. The UCT-CERN Research Centre is part of two experiments running at the LHC: the ATLAS experiment, which explores the fundamental particles of the standard model of particle physics, and ALICE, which is aimed at understanding the quark-gluon plasma.

The nature of its work means that the LHC has been grappling with the problem of big data sets for 20 years. Many of the particles it investigates (like the famous Higgs boson) need to be created by colliding protons at what is close to the speed of light. Because the particles are very rare, tens of millions of collision 'events' are produced per second, which need to be captured and read by a detector. If researchers were to read out every single event, they would need around 40 terabytes per second, which is way beyond the confines of current technology. Using high-speed filtering called 'triggers', researchers can get this down to hundreds of megabytes per second.

While this may already sound like a tall order, it is only part of the big data challenge faced by the LHC. In order to define expectations (so that researchers know what they expect to see), the entire detector is digitally simulated in excruciatingly fine detail, and a computer algorithm is written to simulate the billions of events that might produce a rare particle like the Higgs boson. All of this data then needs to be stored.

Factor into this the collaborations involved (just one of the LHC's seven experiments has 1 000 members belonging to 116 institutions, based in 33 countries), and the scale of the challenge is evident.

The LHC has created a solution to this very big data problem – the Worldwide LHC Computing Grid (WLCG), a form of cloud computing that stores and processes information. It currently has 150 centres in 40 countries and operates through a tiered structure that varies in the funding model, the storage space and the number of cores required.

Creating the infrastructure required to play in this big data league sounds expensive; however, money is not the greatest challenge for UCT, according to Dr Hamilton. "We need the people trained in high-performance computing to operate and administer these facilities," he says. Which is where the WLCG, "one of the largest research computing networks in the world", comes in. "If UCT wants to be a leader in big data research, we need to demonstrate that we can operate a big data centre that participates on the global scale. The WLCG gives us the opportunity to both contribute to one of the largest research computing networks on the planet, and learn from their expertise at the same time."

Complex climate models

The challenge to provide trained people connects all big data projects, whatever their divergent hardware requirements. For instance, acquiring and retaining skilled researchers is the greatest strategic challenge in climate research, according to Professor Bruce Hewitson, director of the Climate System Analysis Group.

This is partly because of the complexity of the big data research challenge in the field, particularly around climate modelling. "There are about 40 mainstream global climate models," says Hewitson. "All produce comparable resolution results, but no model is perfect. Some uncertainty arises from model error – how it's coded up. Some is from the inherent variability in the climate system. So even in one category of modelling, we don't have a clear analytical approach."

Add in regional models and other impact models, and you have a major challenge in distilling information so that it can be analysed and produce defensible regional information. It is the single leading challenge in climate modelling, according to Hewitson, and there has been no substantive advance on it in the last decade.

Researchers acquire skills in this field only by working in an applied environment – learning on the job. However, the academic job market for graduates is minimal, and this is compounded by the likelihood of losing highly skilled people to the private sector or research institutions overseas, where there is more opportunity and higher pay.

"We also have too many single points of failure," says Hewitson. "We have world-class capacity, but if one individual leaves, a whole thread of activity collapses."

However, it is in this world-class capacity that Hewitson finds cause for optimism: "UCT climate research punches above its weight internationally. We have the largest single concentration of capacity on the continent, and are leading research from the perspective of a developing nation."

UCT's climate research also has unique cross-disciplinary skills, and this gives the university a competitive advantage globally. "We have a chance to take a research lead on these global research challenges," says Hewitson, "and to contribute to major policy development in Africa."

In order to take this lead, we will have to find ways to face up to the big data challenges. Part of the answer might lie in the stars.

Big data from the sky

The research field that is wrestling with the biggest data of all is astronomy, and Africa's biggest science project, the MeerKAT Large Surveys, has put UCT at the coalface of this challenge. The MeerKAT radio telescope is a precursor to the square kilometre array (SKA) telescope. Led by four UCT astronomers, MeerKAT is expected to gather up to one petabyte (1 000 terabytes) of data per year, so advanced tools will have to be developed to process, analyse and store the data.

There is nothing small about the SKA – it is the biggest science project ever carried out on African soil. When completed, it will be the world's largest radio telescope, located in Africa and Australia, but shared by astronomers around the globe. Each MeerKAT antenna, which will be incorporated into the mid-frequency component of SKA Phase 1 when that instrument is constructed, stands 19.5 metres tall and weighs 42 tons. The complete MeerKAT array will have 64 receptors – antennas with receivers, digitisers and other electronics. Connected by 170 kilometres of underground fibre optic cable, the 64 receptors will operate as a single, highly sensitive astronomical instrument, controlled and monitored remotely from the MeerKAT control room in Cape Town. When fully operational, the MeerKAT will generate enough data from the antennas to fill about four-and-a-half million standard 4.7-gigabyte DVDs in a day.

An eminent role player in this field has been attracted from Canada: Professor Russ Taylor, one of the founding international SKA project scientists, who joined the university early in 2014 as joint UCT/University of the Western Cape SKA Research Chair, will coordinate a big data vision for radio astronomy in South Africa: "The global SKA big science data world is coming to South Africa this decade," says Taylor, adding that it is probably one of the two projects in the world driving a big data revolution in astronomy.

A research revolution

In addition to his own research with SKA, Taylor will also be working to put South Africa – and Africa – on the map in terms of data capacity. "Global research leadership requires that we have the capacity to extract information from big data," he says, and there is likely to be a limited window of opportunity to establish national leadership in data-intensive research and a global presence in this emerging field.

While big data is by its very nature a massive challenge to the university, it is also a driver of the transformation of science, and by extension, a driver of global change; and UCT is already part of the revolution.

"We are not trying to break into a field where we are absent – we are already there," says Visser. "If we grasp the opportunity to take leadership in this area, we can really make a difference in the country and to science around the world: solving Africa's issues, but also making Africa part of the global solutions."

WHAT'S IN A BYTE?

1 bit	=	a binary digit (0 or 1)
8 bits	=	1 byte (the average sentence equals 100 bytes)
1 kilobyte	=	1 000* bytes (1 kilobyte would be equal to a short paragraph)
1 megabyte	=	1 000 kilobytes (1 megabyte could hold a 200-page book)
1 gigabyte	=	1 000 megabytes (a standard DVD holds 4.7 gigabytes)
1 terabyte	=	1 000 gigabytes (1 terabyte could hold 1 000 copies of the Encyclopaedia Brittanica)
1 petabyte	=	1 000 terabytes (close to 250 000 standard DVDs)

**This is the decimal interpretation most commonly used for disk storage; in a binary interpretation, used for processor or virtual storage, the value is 1 024 for each.*

Dr Francis Thackeray's photograph of Mare Tranquillitas (Sea of Tranquility), including the Apollo 11 landing site, taken from the grounds of the Radcliffe Observatory, Pretoria, in 1969, using a 12½-inch telescope, and signed by American astronaut Neil Armstrong, the first moonwalker.

One of Afrikaans poet C Louis Leipoldt's very many day planners – tiny diaries filled with the day-to-day matters that needed his attention. Leipoldt was encouraged at an early age to read widely, and was given a grounding in several languages and the natural sciences, particularly botany and geology. Whenever the family visited Cape Town, he was sent to his father's friends, such as Professor PD Hahn, for special instruction.

UCT's many books on marine biology include a recent donation from the Department of Biological Sciences: a volume on nudibranchs dating to 1854, the British monograph *Nudibranchiate Mollusca* (Joshua Alder, Albany Hancock, Ray Society). These volumes feature beautiful, hand-coloured illustrations, such as this *Thecacera pennigera* (winged thecacera), a species of sea slug.

The Cape Mountain Club kept an extensive photographic collection, including glass plate slides (in picture) and minutes and correspondence from the past century, reflecting the landscape and vegetation over the years, including events such as snow on Table Mountain, and the existence of the historic fish market in Cape Town.

Illustrations inside the 1930 publication *Rock Paintings of South Africa*, which includes a folding map showing the specific location of works, and an introduction and descriptive notes by Dorothea Bleek. This forms part of Special Collections' UNESCO-recognised Bleek and Lloyd collection.

A photograph of Wilson Cave, a small but highly decorated cave near Hunt in Texas Hill County with over 800 feet of passageway, taken in 1990. It belongs to the South African Speleological Association's comprehensive collection of photographs, minutes, correspondence, general records and cave maps gathered between 1954 and 1999.

A cardboard model of a brain and head measure belonging to the JG Davidson phrenological collection, which includes correspondence, minutes and reports of the British Phrenological Society. Phrenology, the study of skulls to determine an individual's character and mental capacity, enjoyed some popularity in Europe in the early 19th century, but is now considered a pseudoscience.

An archival image of the *Thomas B Davie*, a research ship named after the former UCT principal and one of several research vessels the university has owned over the years. It is part of the TB Davie collection, which includes cruise reports, asset registers, charters of the vessel and photographs. The 205-ton Thomas B Davie was commissioned after its predecessor the John D Gilchrist's sea days ended in 1966. Launched in 1965, the new vessel permitted longer cruises further off shore, notably two visits to the Vema Seamount in the Atlantic Ocean.

THIS WILL MAKE YOU SMARTER

Photos by **Je'nine May**

If you had to take away one life lesson from the sciences – one small fact that could expand your world – what would it be? We asked young scientists at UCT what they've learnt from their subject – and what others stand to learn.

Morema Moloisi
Astrophysics

"I would like people to know about the sun. The first thing I'd like to tell them is that the sun is also a star, just like all the other stars which you see in the night sky. The only difference is that it's the star in our solar system, and it's closer to us than all the other stars, which are much, much further away. The second thing is that the sun is not really yellow, because it's emitting white light. It's actually a white star. It's just that our atmosphere refracts the light from the sun and makes it look yellow."

Samantha Julius
Chemistry

"Everything that exists in this world is made from just a few different atoms. It is so intricately connected that a single atom missing or out of place determines the difference between a disease or a perfume. Everything that is, exists for a purpose."

Simeon Brown
Biochemistry and genetics

"I think that people shouldn't just swallow everything they see or hear from people or the media. Make your own opinions. Form your own conclusion. Think about it for yourself. By just swallowing everything whole, you'll just get fat from the force-feeding of information. Think for yourself. The world is more interesting with your mind in it."

Simone le Roux
Biochemistry and human physiology

"Studying the human body and how it works, you realise how amazing your body is and how much it does for you. It really is the least you can do to take care of your body. It's much easier to stay healthy than it is to get healthy again. You shouldn't wait until something goes wrong before you start looking after your body. I think it's really important to educate yourself about what you need to be healthy. There are so many products out there that make frankly ridiculous health claims, and people waste money on them when there are way cheaper, way easier alternatives. Learn about what you need, read the labels on the products you buy, figure out for yourself if a product is really going to help you. There is so much information available now that there's no excess for being fooled by some fancy packaging."

Candice Koopowitz
Archaeology

"Archaeologists look to tell the story of how we came about and the different paths that were taken by our ancestors to get to where we are today. It provides people with an understanding and sense of equality and belonging in that we're all humans, evolved from the same ancestors, who overcame the same problems."

James Pelser
Genetics and microbiology

"To the average person on the street, science is daunting – often seen as more difficult than it actually is. However, it is only with science that we have advanced this far, and only with it can we advance further."

Dr Takalani Theka
Chemistry

"According to the World Health Organisation, more than 70% of the world's population uses traditional medicine. So it's not surprising that scientists all over the world are involved in research on medicinal plants, trying to find out which chemicals in the plants have healing properties. Scientists then 'make' or synthesise the chemicals in the laboratory … A famous example would be the bark of the willow tree, which patients were traditionally advised to chew in order to cure pain and fever. Scientists studied this medicinal plant and later 'made' or synthesised aspirin. I study the chemical compounds in the essential oils obtained from medicinal plants that can be used in pharmaceuticals, cosmetics, perfumery and food products."