

SCIENCE FOR SOUTH AFRICA

quest

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*Shooting for
the stars*

*Science and technology
enable the disabled*

*Chasing the rain
in Jonkershoek*

In the next issue



The theme of the March-April issue will be 'plant health', as *Quest* joins the global community in celebrating the International Year of Plant Health (IYPH 2020), proclaimed by the United Nations General Assembly.

The goal of IYPH 2020 is to raise awareness on how protecting plant health can help end hunger, reduce poverty, protect the environment and boost economic development – all of which are required to achieve the UN Sustainable Development Goals.



Quest aims to promote interest in science amongst the youth and general public. It is distributed free to all public high schools in South Africa offering science at Grade 10-12 level, and to learners at selected science events.

It is also distributed to universities and training colleges, and some libraries, science centres, government departments, parliamentary committees, embassies and non-governmental organisations.

To increase *Quest*'s reach, it is now also freely available on a dedicated website. Visit:

questonline.org.za

or scan the QR code overleaf.

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Enabling the disabled

The theme for this issue of *Quest* is Disability, which is any continuing condition that substantially restricts a person's life activities. A disability may be present from birth or occur as a result of an accident, illness or the ageing process.

According to StatsSA data from the 2011 national census, some 7.5% of South Africa's population lives with a disability. The National Council for Persons with Disabilities organises the annual Casual Day on the first Friday of September as an awareness and fundraising campaign for organisations supporting the disabled, and the country also commemorates National Disability Awareness Month for the month leading up to 3 December, which was proclaimed the International Day of Disabled Persons by the United Nations General Assembly in 1992.

In recent years, technological advances have helped ease the challenges faced by disabled people, and the big players in the global tech industry have recognised the role they can play. Google introduced its Impact Challenge: Disabilities in 2015, and gave \$20 million to 29 organisations using technology to help solve accessibility challenges around the world. And in May 2018, Microsoft pledged \$25 million towards the development of tools

that use artificial intelligence (AI) for the benefit of the disabled. The funds are being channelled through a five-year grant initiative called AI for Accessibility, which focuses on three areas: employment, daily life, and communication and connection. The more than 30 grantees to date include developers of speech therapy video games powered by AI; an app that converts specific sounds into coloured flashes to warn deaf people of fire alarms, doorbells, etc; a neuromuscular-sensing 'watch' to control digital devices using micro-movements of the hands and arms; and a social app to connect people with special needs.

In this issue, we highlight some international examples of such technological advances, while also drawing attention to the diverse ways in which researchers at local universities 'enable the disabled'.



Sue Matthews
QUEST Editor

Ukukhubazeka kuyinoma isiphi isimo esikuvimbela ukuba uzenzele izinto eziyisidingo, eziwayelekile empilweni. Kungenzeka uzalwe nakho ukukhubazeka noma ukhubazeke ngenxa yengozi, ukugula noma ukuguga.

Translation by Zamantimande Kunene



PROTECTING Paralympians

Paralympians ‘push the envelope’ as hard as any elite athlete, but they have additional medical challenges that Stellenbosch University researchers are helping them overcome.

The Institute of Sport and Exercise Medicine (ISEM) at the Faculty of Medicine and Health Sciences is involved in several studies investigating injury and illness in Paralympic athletes. ISEM’s director, Professor Wayne Derman, has served as an official doctor for the South African Paralympic team, so is well placed to discuss some of the issues and the range of solutions that his team is developing.

“How is the quintessential Olympic athlete – Usain Bolt – different to a Paralympic star like sprinter Jonnie Peacock?” asks Prof. Derman. “Both are exercising at peak performance, under extreme cardiovascular stress. But there’s another layer of complexity for para-athletes that may not be immediately apparent.”

People with disabilities are, in general, at higher risk for health problems. For instance, common conditions such as cardiovascular disease, diabetes, cancer and chronic pulmonary disease are more prevalent among wheelchair users, who are forced to be sedentary. There may be additional medical issues; people with spinal cord injuries, for example, are prone to urinary tract and skin infections, possibly due to altered immune function. Not surprisingly, more injuries and illnesses are reported during the Paralympic Games than the Olympics.

Doctors face this extra complexity when approaching diagnosis in the young field of disability sports medicine.

“For instance, how do you apply standard tests to tell if someone in a wheelchair has suffered a concussion? You can’t use the standing balance test. In the case of a runner with a prosthesis, how do you compare the different sides? We have to adapt, to understand that the sound leg takes an extra load, so that’s where problems are likely to occur.”

Prof. Derman and his colleagues have put together a web-based solution to monitor injuries and illnesses during the Games. This allows doctors to input data in real time, forming a picture of where the issues lie. Once problems are identified, the researchers determine the cause and mechanism of the injury, using tools such as video and biomechanical analysis.

Preventative measures are put in place and evaluated with follow-up studies. Sometimes problems are fairly easily rectified. “For instance, we were seeing horrendous knee injuries in ice-sledge hockey,” Prof. Derman recalls. “After analysing the video footage, the medical team recommended adding rails to the sleds – and the knee injuries went away. In five-a-side football, blind players are meant to shout ‘Voy!’ (‘I’m going!’) as they run towards the ball. But they often don’t, preferring stealth, which can lead to concussions. We’re hoping to see this risk addressed through better rule adherence and protective headgear at the 2020 Tokyo Summer Paralympics.”

Issued by Stellenbosch University (SU). The article was originally published in the annual report ‘Research at Stellenbosch University 2018’, compiled by the Division for Research Development, and was posted on SU’s news page on 26 September 2019: www.sun.ac.za



A helping hand

Worldwide, there are more than three million people who have had one or both arms or hands amputated, and the vast majority of these are in developing countries.

Since commercially available prostheses are very expensive – starting at about R300 000 for myoelectric prostheses but exceeding R1 million for advanced models – many amputees use a hook or claw prosthesis, or nothing at all. Here, *Quest* explores some initiatives at local universities to develop more functional yet affordable options.

'Myoelectric' = relating to electrical signals generated by muscles

Touch Hand

In 2013 Drew van der Riet set out to develop a low-cost prosthetic hand for his Master's project in mechanical engineering at the University of KwaZulu-Natal (UKZN). By the end of that year, he had invented the 3D-printed Touch Hand, so named because it incorporates an innovative sensory feedback system that restores an amputee's sense of touch, allowing for the detection of pressure, vibration and temperature. Movement of the hand relies on electromyography (EMG), which means that it is controlled by electrical signals generated by contracted muscles in the residual forearm.

Drew formed the company Touch Prosthetics with his supervisor, Professor Riaan Stopforth, who heads the Stopforth Mechatronics, Robotics and Research Lab in UKZN's Department of Mechanical Engineering. In mid-



Drew van der Riet, Greg Jones, amputee John Harris and Riaan Stopforth following testing of Touch Hand 2 in 2015.



Amputee Darren Hauptfleish writes his own name during testing of Touch Hand 4.

2014 another Master's student, Greg Jones, joined them to work on a second iteration. Touch Hand 2, completed in mid-2015, featured jointed fingers with segments that could be individually moved via cables, driven by a printed circuit board (PCB) housed in the palm. Six motors and three torque and speed settings meant that the hand could perform a variety of gestures and grips.

"Touch Hand 1 was very rough in terms of looks, because there were lots of wires sticking out," explains Prof. Stopforth, who acts as CEO of the company (Drew remains involved but relocated to the USA in 2016 to work at Apple, initially). "We then developed Touch Hand 2, which looked like a human hand, but the amputees who assisted with the testing indicated that they do not really want the resemblance to a human hand, but they needed it to be more functional for their daily activities. So Touch Hand 3 was developed, with better functionality, but we still needed to improve on this."

"Touch Hand 4 was developed in a collaborative effort with the mechatronics team led by Prof. Theo van Niekerk at Nelson Mandela University (NMU), and underwent testing in December 2018. An NMU Master's student, Kiran Setty, worked with BunnyCorp on the design aspects to improve the functionality of the hand. Rapid 3D assisted us with the optimisation for the 3D printing aspects of the research, while numerous other companies in South Africa assisted with components."

"At the moment there is another NMU mechatronics student, Kyla Purdon, working on the EMG electrodes, and the control of the hand accordingly. She is also optimising some of the aspects we felt were important to improve upon, following the tests we conducted."

The advantages of the Touch Hand, apart from its low cost, are that it is highly customisable and upgradeable. The prosthesis would be specifically made for each amputee and uniquely suited to their individual needs and budget, with different choices in batteries, motors and other electronic components. Each component can be upgraded separately, meaning that it would be easy and affordable to stay up-to-date with the latest technology. In addition, the modular design means that

any damaged components can be replaced, rather than the entire Touch Hand.

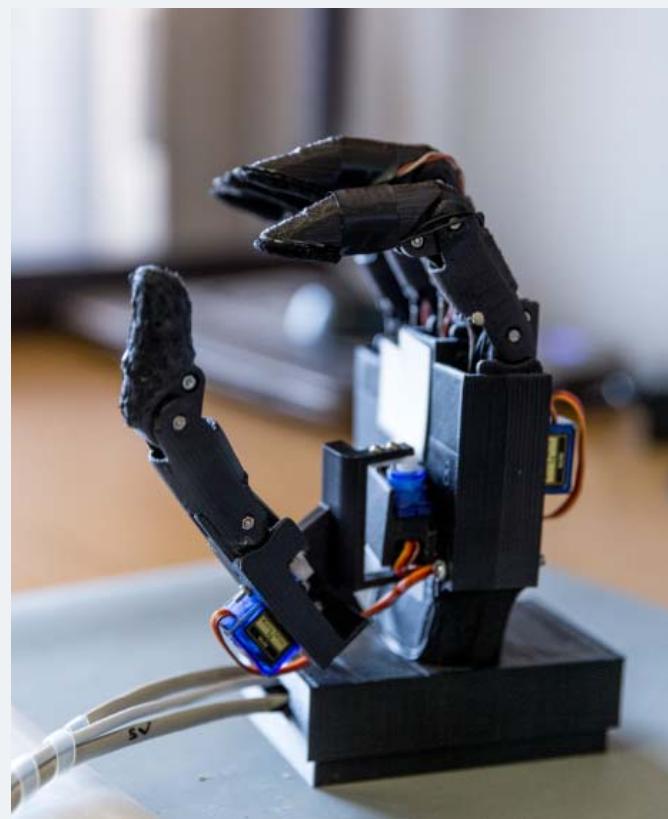
The Touch Hand team has been invited to participate in Cybathlon 2020 in Zurich, Switzerland, in May 2020, but will not be able to attend without sponsorship to cover the costs involved. The event is billed as a unique championship in which people with physical disabilities compete against one other to perform everyday tasks using state-of-the-art technical assistance systems.

"Attending the Cybathlon is important to us, as it is not only a way for us to represent South Africa, but also for us to compare the performance of our Touch Hand with other hands developed around the world," says Prof. Stopforth. "We hope that once we have been able to compete, a company will see the value of such a product and – with their infrastructure already in place – assist in the production and also subsidise the cost of the hand, so that people in South Africa and Africa can benefit from it."

- For more information, and to view a video of the Touch Hand in action, see: www.touchprosthetics.com

3D Prosthetic Hand

At the University of the Witwatersrand (Wits), lecturer Abdul-Khaaliq Mohamed and his students in the School of Electrical and Information Engineering have been developing their '3D Prosthetic Hand', the name referring to the fact that it is 3D printed. The project started in 2014, although the concept was conceived in 2008, when Mr Mohamed was searching for a topic for his Master's



The 3D Prosthetic Hand has not yet been integrated into a socket so it cannot be worn, but the fine-tuned grip control allows testers to hold a marble, a pen or even a thin plastic cup without crushing it.



Abdul-Khaaliq Mohamed with the 3D Prosthetic Hand.

research. He wanted to do something involving machine learning and artificial intelligence in the human body, and came across the idea of using thoughts to control a robotic hand. He ended up restricting his Master's project to an analysis of brain signals involved in hand movement, using electroencephalograms (EEG) that measure the brain's electrical activity via electrodes placed on the scalp. Subsequently, he started the 3D Prosthetic Hand project so that his undergraduate students could take on aspects of its development as their required final-year project.

At this stage the hand is not controlled directly by brain signals, but by electromyography (EMG), like the Touch Hand. Electrodes are placed over the biceps and triceps muscles on the upper arm, and the electrical activity associated with muscle contractions sends signals to the hand, making the fingers move. A feedback system from sensors on the fingertips causes vibrations in a cuff worn on the upper arm, so that the user can learn to grip objects with the correct amount of pressure. The hand is not yet integrated into a socket, so it cannot be worn as a prosthesis, but Mr Mohamed envisages that it could be commercialised in about three years, with an expected retail price of R25 000 or less.

One of the students who worked on the hand in 2017, Irfaan Mohamed, is now doing his Master's degree on a

self-adjusting prosthetic socket for lower-limb amputees. His personal website (<https://irfaanmohamed.com/>) showcases the media coverage for the 3D Prosthetic Hand project, as well as his own contributions. He and his classmate Nabeel Seedat were responsible for perfecting the hand's 'tripod pinch' – the grip used to hold a pen – after which sensors were added to the fingertips to enable the hand to sense force. The paper they co-authored with Mr Mohamed, titled 'Custom force sensor and sensory feedback system to enable grip control of a robotic prosthetic hand', was presented at the International Conference on Biomedical Robotics and Biomechatronics (BioRob2018) in the Netherlands in August 2018.

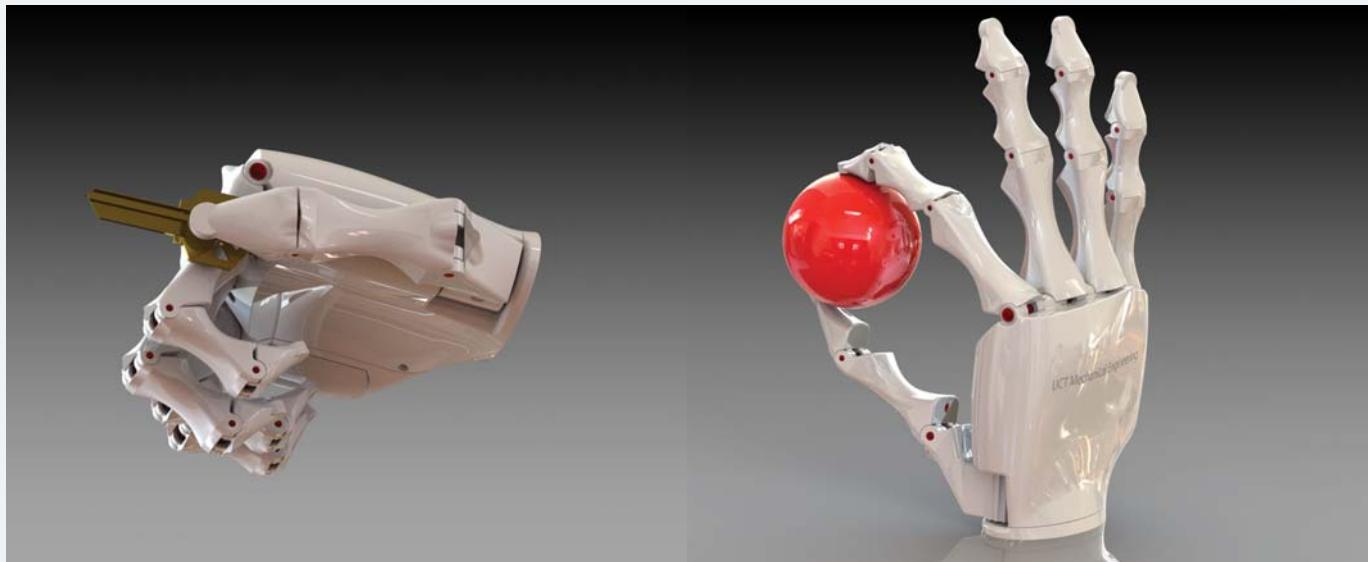
Most recently, the project team entered the 3D Prosthetic Hand in the Inventor's Garage competition at the SA Innovation Summit, held in Cape Town in September 2019. A total of 146 entries from across Africa were received, and the 3D Prosthetic Hand was selected as one of three finalists in the Healthcare category. As Abdul-Khaaliq Mohamed explained when interviewed on the Gareth Cliff Show on 16 September: "We didn't win, but the exposure was wonderful and we had the opportunity to meet lots of similar-minded entrepreneurs and potential funders and collaborators."

- Search YouTube for 'Wits 3D Prosthetic Hand' to view a number of videos featuring various team members demonstrating the hand, including one from SABC's Expresso Show in November 2017 and a more recent interview from the Innovation Summit in September 2019.

Tenim Hand

University of Cape Town mechanical engineering student Severin Tenim and his supervisor, Associate Professor George Vicatos, took a different approach for the Tenim Hand, developed as Severin's Master's project. Rather than making use of any electronics, this was a mechanically operated prosthesis relying on levers, pulleys, cables, bearings and springs. In common with many other mechanical prostheses, a conventional socket was used to attach the hand to the amputated arm, and the hand was operated via a metal cable linked to a shoulder harness, so that movement of the shoulder muscles changed the tension on the cable. The cable ran through the 'wrist', and pulling on it would make the fingers grip until the hand was closed. A knob adjacent to the little finger allowed the fingers to be locked in position, while the thumb was attached by a swivel so that it could rotate either towards or away from the fingers. The 'skin' was 3D printed by the Centre for Rapid Prototyping and Manufacturing at the Central University of Technology (CUT) in Bloemfontein, according to Severin's design plans.

A provisional patent for the Tenim Hand was registered in the United Kingdom, and Severin noted in his thesis, submitted in September 2014, that the prototype cost less than R12 000 to make and assemble. The following month he and Prof. Vicatos were given the Cutting Edge award for their invention at the *Popular Mechanics FutureTech Conference*.



The original Tenim Hand shown here was a mechanically operated prosthesis, controlled by a metal cable linked to a shoulder harness. It is now being updated to an electromechanical prosthesis, activated by electric motors.

After graduating, Severin relocated to Dubai, where he now holds the post of Strategic Project Manager at a large construction company. In 2017, however, Ameen Bardien – a biomedical engineering student under the supervision of Associate Professor Sudesh Sivarasu at UCT's Medical Devices Lab – began work on updating the design of the Tenim Hand. The goal is to convert it to an electromechanically actuated prosthesis, which would place the Tenim Hand in the large gap between myoelectric prostheses, costing as much as R500 000, and cable-driven prostheses, costing as little as R4 000.

Work on the new project began with addressing the issues that were found during the design validation Tenim had conducted as part of his thesis. Issues already resolved include redesigning the thumb so that larger objects can be held, and adjusting the closing trajectories of the fingers so that they grip around objects better, instead of pushing them away with the fingertips. The new parts were 3D printed at UCT's Medical Devices Lab.

"Current work on the Tenim Hand project includes the integration of a wrist adjustment mechanism and the electromechanical actuation system," explains Ameen.

"The wrist mechanism allows the hand to be manually pronated or supinated (rotated) so that the user can grasp objects more easily. The electromechanical actuation of the hand aims to help prosthesis users who struggle with the immense amount of strain on their shoulders when using cable-driven prostheses. These two systems are currently being manufactured and tested for integration into the Tenim Hand."



- A News24 video of the original prosthesis is available on YouTube. Search for 'Tenim Hand'.

A Lego prosthesis

David Aguilar, a young Spaniard who was born without a right forearm, built his own prosthetic arm using Lego pieces while still at school!

He is now a bioengineering student in Barcelona, and has made a number of different versions of the arm, each more advanced than the last.

Search YouTube, where he's profiled in a number of videos – most recently on the Lego Channel – or check out David's own video 'Mk-III, the ultimate Lego prosthetic arm' on his YouTube channel, Hand Solo. Watch and be inspired!



David Aguilar with the first three versions of his prosthetic arm, and with the Lego kit that he used to build 'Mk-III'.

Tukkies for the hearing impaired

The University of Pretoria is at the forefront of research and development relating to deafness

While some people are born deaf – often because of complications or exposure to disease during pregnancy, but also due to genetic factors – others experience loss of hearing to varying degrees during the course of their lifetime. In children, this may result from illnesses such as measles, mumps or meningitis, but teenagers and adults are more susceptible to noise-induced hearing loss from loud music, sporting events and working environments. Head injuries, neurological disorders such as strokes and multiple sclerosis, and certain medications and chemicals can also cause hearing impairment, plus hearing deteriorates as part of the ageing process.

Here, *Quest* highlights some of the contributions by University of Pretoria researchers and specialists in assisting the hearing impaired.

Ossicle implants

In March 2019, Professor Mashudu Tshifularo from the university's Department of Otorhinolaryngology (ear, nose and throat [ENT] surgery) made headlines when he

HOW WE HEAR

Sound waves enter the ear and travel through the ear canal to the eardrum, causing it to vibrate. The vibrations move the middle ear's three tiny bones, or ossicles, which are formally named the malleus, incus and stapes, but commonly called the hammer, anvil and stirrup.

This movement in turn causes the fluid in the inner ear's cochlear to move, setting the hair cells in motion.

The hair cells change the movement into electrical impulses that are sent through the auditory (hearing) nerve to the brain.

The auditory cortex of the brain interprets these electrical impulses as sound, and processes the information.



Prof. Mashudu Tshifularo during the world's first implant of 3D-printed ossicles at Steve Biko Academic Hospital in Pretoria in March 2019.

performed the world's first implant of 3D-printed ossicles at Steve Biko Academic Hospital.

Prosthetic implants for ossicular replacement have long been commercially available for this surgical procedure, and are made from a variety of materials including fluoroplastics such as Teflon, polyethylene, or metals like stainless steel, nickel alloys, platinum and titanium. Total implants replace the entire ossicular chain – malleus, incus and stapes – with a Total Ossicular Replacement Prosthesis (TORP), but a Partial Ossicular Replacement Prosthesis (PORP) can be used where the stapes is still present. These implants come in a variety of sizes for optimal fit, and have some strange shapes that look nothing like human ossicles!

Prof. Tshifularo used a different approach, as he worked with medical product development firm BunnyCorp and 3D printing specialists Promake International to construct a tiny titanium prosthetic that more closely resembles the real thing.

The operation was featured on *Carte Blanche* and can be viewed on YouTube (search for '3D-printed middle ear transplant'). According to a news post on the University of Pretoria's website in mid-July, the operation largely restored the hearing of the patient, but ethics approval must now be obtained before proper clinical trials are conducted. The operational procedure, together with the likely outcomes and possible complications, will also be written up.

Cochlear implants

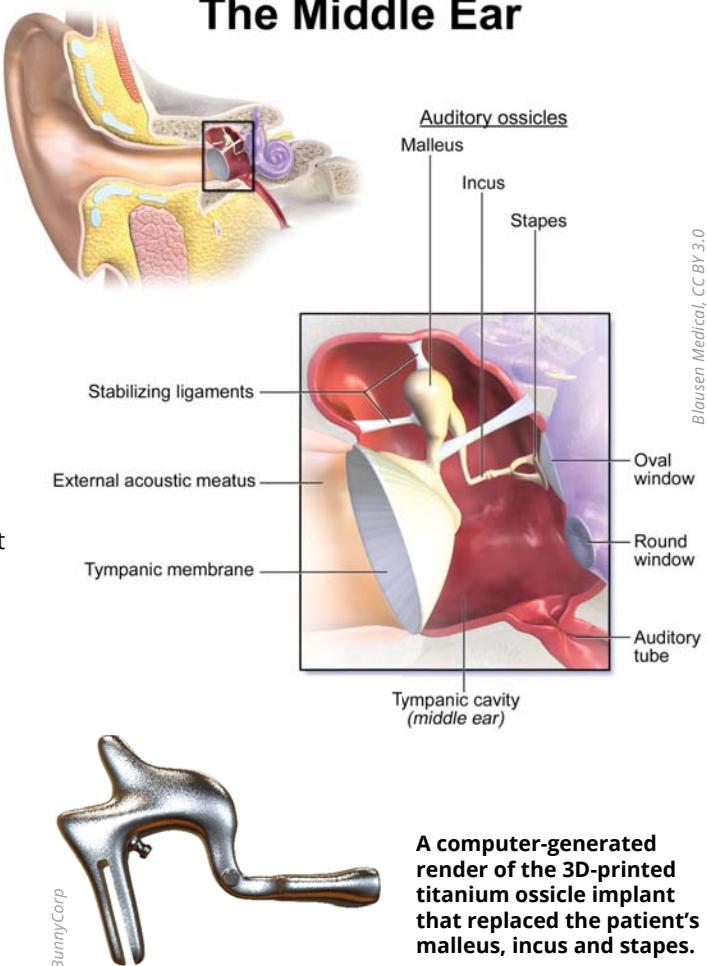
People who are profoundly deaf or severely hard of hearing may benefit from a cochlear implant. This is an electronic hearing device consisting of an external part



Accessories for modern cochlear implants even allow for water-based activities.

Cochlear Aqua Plus, CC BY-NC-ND 2.0

The Middle Ear



A computer-generated render of the 3D-printed titanium ossicle implant that replaced the patient's malleus, incus and stapes.

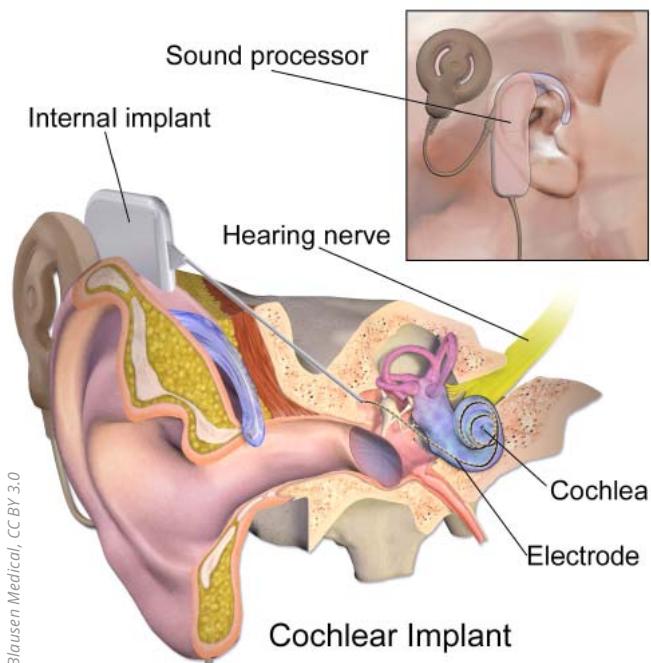
that is worn behind the ear, and an internal part that is surgically positioned. While hearing aids essentially amplify sound, cochlear implants are designed to bypass the damaged cochlea by electrically stimulating the auditory nerve.

The process is as follows. The external sound processor picks up sounds and converts them into digital information, which is then transferred through the coil to the internal implant. The implant converts the digital information into electrical signals and sends these down to the electrode array in the cochlea. The electrode array stimulates the hearing nerve, which sends information to the brain.

Cochlear implants do not restore hearing to 'normal' because the hearing experience is quite different from natural acoustic hearing, so it takes time for recipients to adjust. But they can help with understanding speech and hearing sounds in the surroundings, and also offer young children the opportunity to learn to communicate through spoken language. They are extremely expensive, though, both for the initial implantation and ongoing maintenance and support, requiring a lifelong financial commitment. In South Africa, this means that most cochlear implant recipients – or their parents in the case of children – need to have significant financial resources and/or membership of a private medical aid scheme. There are a few government-funded cochlear implant programmes, but recipients must meet strict criteria to be eligible for selection.



Dr Talita le Roux (in beige jacket) and some of the postgraduate students she supervises at an international conference to present their research related to cochlear implants.



Blausen Medical, CC BY 3.0

A cochlear implant works as follows. The external sound processor picks up sounds and converts them into digital information, which is then transferred through the coil to the internal implant. The implant converts the digital information into electrical signals and sends these down to the electrode array in the cochlea. The electrode array stimulates the hearing nerve, which sends information to the brain.

The University of Pretoria's Department of Speech-Language Pathology and Audiology has a close association with the Pretoria Cochlear Implant Unit. Dr Talita le Roux and the postgraduate students she supervises conduct research related to cochlear implants, such as the predictive factors of positive implantation outcomes, the health-related quality of life of adult and paediatric recipients, and family-centred care during the paediatric cochlear implantation process.

Hearing assessment apps

In March 2016, the free hearZA® app was launched in South Africa to coincide with World Hearing Day. Developed and validated by a team of researchers led by Professor De Wet Swanepoel of the university's Department of Speech-Language Pathology and Audiology, this mobile app allows members of the public to test their hearing using any Android or iOS device with

CURRICULUM CORNER

LIFE SCIENCES: GRADE 12

Responding to the environment: Humans

PHYSICS: GRADE 10

Sound waves; Pitch and loudness

earphones or headphones. The two-minute test is easy to use and generates a hearing score on completion, but is only accurate for people who are at least 16 years old. The app detects users' location, and refers those who fail the test to their closest hearing healthcare provider for further assessment and assistance.

HearZA® is a digits-in-noise (DIN) hearing test, in which recorded digit triplets (e.g. 5-3-7) are played over background white noise. People who are hard of hearing typically struggle to follow conversation in noisy settings, so this is a type of speech-in-noise (SIN) test. Traditionally, SIN tests use sentences, but this can be challenging in a country like South Africa, where so many languages are spoken. The first DIN test for landline telephone use was developed in the Netherlands in 2004 and subsequently implemented in other countries, but relatively few people in South Africa have access to landlines, hence the development of hearZA® – the world's first smartphone-based DIN test.

Since then, Prof. Swanepoel and his team have been involved in the development of a number of other mobile applications. In October 2018 a version for use in the United States, called hearScreen USA, was launched with the American Academy of Audiology, and in March 2019 the hearWHO app developed for the World Health



Prof. De Wet Swanepoel demonstrating the hearZA® app to a user.

Organisation was released on World Hearing Day. They have also developed clinical (medically regulated) apps that are not available on app stores, but are provided to healthcare providers as affordable and mobile hearing assessment tools for pure tone audiometry. These tests, made available in partnership with the hearX Group, determine hearing sensitivity using tones played at different pitches.

SPEECH-LANGUAGE PATHOLOGY AND AUDIOLOGY

'Communication is the essence of human life' J. Light

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More information:
<https://www.up.ac.za/speech-language-pathology-and-audiology>

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Disability due to Neuromuscular disease

Francois van der Westhuizen reports on South African participation in the International Centre for Genomic Medicine in Neuromuscular Disease

Neuromuscular diseases (NMDs) affect approximately 20 million children and adults globally. They either result in premature death or are chronic diseases causing lifelong disability with economic impact. They include many different disorders affecting muscle and nerve function and account for 20% of all neurological diseases. Examples include muscular dystrophies, motor neurone diseases and mitochondrial diseases.

Most NMDs are genetic single-gene disorders, with many different causative genes being discovered. In developed countries, precise genetic diagnoses and gene discoveries are already having an important impact on patient care and health outcomes. Unfortunately in developing countries, such as South Africa, this is not the case and the great strides in research that are required to develop such genetic diagnoses in our country have not been forthcoming in recent decades.

The newly established International Centre for Genomic Medicine in Neuromuscular Disease (ICGNMD) – partly funded by the MRC (UK) for five years from July 2019 – has the mission to harness genomics to understand disease mechanisms and improve the health outcomes of children and adults with serious NMDs on a global scale. It is led by the University College London and Cambridge University, and includes partners from five developing countries: South Africa, Brazil, India, Zambia and Turkey.

The main objectives are to build NMD cohorts in these countries, identify the genes involved in the disease in each population, and build human capacities in each country as well as international networks that are sustainable. Reaching these objectives will greatly help to address the treatment of the various NMDs.

For South Africa's participation, experienced researchers and clinicians at the following universities have formed a core team:

- Prof. Francois H van der Westhuizen (coordinator and NMD researcher), Centre for Human Metabolomics, North-West University: Potchefstroom
- Prof. Izelle Smuts (paediatric neurologist), Department of Paediatrics, University of Pretoria
- Prof. Jo Wilmshurst (paediatric neurologist), School of Child and Adolescent Health, Red Cross War Memorial Children's Hospital, University of Cape Town
- Dr Franclo Henning (neurologist), Division of Neurology, Stellenbosch University
- Prof. Jeannine Heckmann (neurologist), Division of Neurology, Groote Schuur Hospital, University of Cape Town
- Prof. Soraya Bardien (geneticist), Division of Molecular Biology and Human Genetics, Stellenbosch University.

The success of this ambitious study for South Africa will greatly depend on the extent to which patients can be recruited and how well the complex, population-specific clinical and genomic data can be scrutinised. It will also depend on collaborations with all stakeholders in South Africa. The centres already participating have a database of patients visiting these clinics, as well as established networks and collaborations (e.g. contact with local branches of the Muscular Dystrophy Foundation of South Africa). We would like to expand the knowledge of this study so that broader access of patients with an NMD, and other collaborations with these clinics, can be established over the next five years.

Prof. Francois H. van der Westhuizen heads the Mitochondria Research Laboratory at North-West University: Potchefstroom, where he is Professor of Biochemistry and Deputy Director of the School of Physical and Chemical Sciences.

This article is republished with permission from the magazine of the Muscular Dystrophy Foundation of South Africa, MDF Magazine, Issue 59, August 2019.

A brief history

of a life lived with MND

The late Professor Stephen Hawking – the most famous disabled scientist of modern times – had a rare, early-onset and slow-progressing form of motor neurone disease (MND). He was diagnosed when he was 21 years old and given only a few years to live, but survived for more than 50 years before dying in March 2018 at the age of 76.

MND destroys motor neurons, the nerve cells that control the movement of the voluntary muscles. Hawking had the most common type of MND called amyotrophic lateral sclerosis (ALS), which affects both upper motor neurons in the brain and lower motor neurons in the brain stem and spinal cord. Signals to all voluntary muscles are disrupted, and muscles weaken and waste away over time, so affected individuals lose their ability to move their arms and legs or even to speak, swallow or chew. Death is usually due to respiratory failure as the muscles responsible for breathing weaken. The average life expectancy is three to five years after diagnosis, but about 10% of affected individuals survive for at least 10 years.

Hawking remained active until shortly before his death, working with colleagues on a scientific paper on black holes, the subject for which he was best known. He gave his final public lecture in Cambridge just a few months earlier, being able to communicate using a voice synthesiser. Although he was British, this computer-generated ‘voice’ had a slightly American accent, but Hawking refrained from changing it as it had become recognisable as his own.

The communication system was provided by Intel from 1997, with upgrades made every few years as technological advances allowed. Initially Hawking was able to use his thumb to operate a clicker switch,



The viral Ice Bucket Challenge of 2014 was designed to raise money and awareness for ALS. Although there were concerns that the message was lost along the way, a report released in mid-2019 showed that the campaign raised \$115 million in donations.



NASA/Paul E Alers

The communication system used by Prof. Stephen Hawking relied on the Assistive Context-Aware Toolkit (ACAT), which has been made available as free, open-source software to assist others with severe speech problems. The ACAT page on the Intel Open Source website features a recorded message from Hawking about how science and technology can help people with disabilities. <https://01.org/acat/>.

highlighting characters and words on a keyboard displayed on his computer screen to type out sentences, which were then sent to the voice synthesiser. By 2005 he had lost the ability to use the clicker, so an infrared sensor was attached to his spectacles, and Hawking used his cheek muscles to control the cursor on the screen. The Assistive Context-Aware Toolkit (ACAT) software developed by Intel included a SwiftKey predictive text algorithm, which used machine learning trained on Hawking's books and lectures. It also allowed him to control his mouse in Windows, so he could use email, internet and word-processing software. A webcam meant that he could even make Skype video calls.

This technology is an advanced form of Augmentative and Alternative Communication (AAC), but low-tech options, such as word- and picture-boards with mouth-stick or laser pointers, are used by many people with speech disabilities.

- ALS is also known as Lou Gehrig's disease, after a New York Yankees baseball player who had to retire from the game in 1939 and died from the disease two years later. There is evidence to suggest that concussive head and neck trauma associated with sporting activities increases the risk of developing ALS. Former Springbok rugby players Joost van der Westhuizen and Tinus Linee both died from ALS.

High-tech aids for the blind and visually impaired

Quest explores some advances in assistive technology

Worldwide, more than 36 million people are blind and at least 220 million have moderate to severe vision impairment. There are a variety of aids to assist people with this kind of disability in their daily lives, from talking watches and Braille tape measures to coin selectors and special telephones. In the last few years, however, technological advances have made a huge difference in easing the challenges faced by the blind and visually impaired.

For learners and students, **Braille notetakers** are especially useful as they allow notes to be recorded during class or assignments to be typed and submitted. The different models come with either a standard QWERTY keyboard, a Perkins-style Braille keyboard or a touchscreen. They can be connected via USB, Bluetooth, Wi-Fi or serial port to the internet, as well as to normal printers and monitors, so that assignments can be emailed, printed or displayed for a sighted teacher to mark. Most advanced notetakers include both Braille and speech output, allowing the learner to check whatever has been typed and review it for studying purposes via either a refreshable Braille display or the built-in speakers. The devices can also be used to read or listen to books, play music or podcasts, record voice notes or lectures, do calculations and send instant messages. When connected to a computer with installed screen-reading software, such as JAWS (Job Access With Speech) or NVDA (NonVisual Desktop Access), they allow the user to read or listen to text on the computer screen.

Printed text can be read using a stand-alone reading machine such as the Eye-Pal Solo, which resembles an overhead projector. It scans the page of printed material and reads it aloud, and the text can be saved electronically on a USB flash drive.



Jordan Nicholson, DisabilityIN, CC BY-ND 4.0



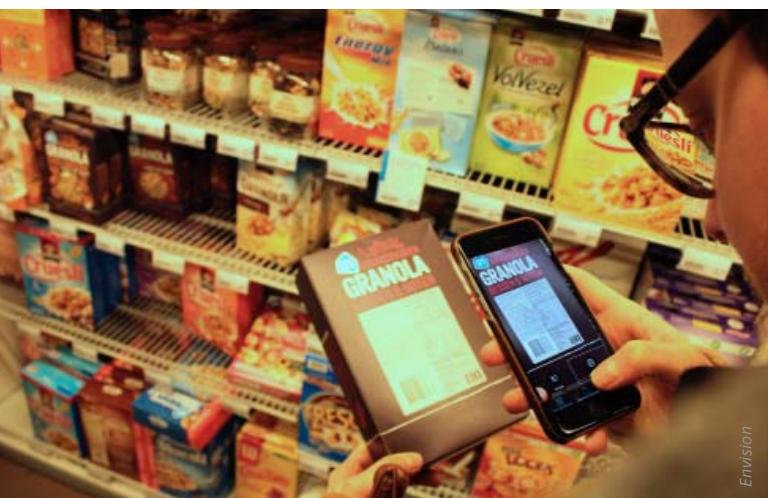
Eli Gitelman, CC BY-SA 4.0

A considerably more versatile and mobile option is the **OrCam MyEye** – a tiny camera that can be attached to any pair of eyeglasses. Billed as ‘the world’s most advanced wearable assistive device’, it uses artificial intelligence and machine learning to read printed and digital text aloud, and can also recognise faces, currency and even details about products, using barcodes to identify the brand and other details, if available. It’s operated by pressing a button on the device or via gesture control, by simply pointing a finger at the object being viewed. Two other gesture controls can be used to stop reading and to tell the time. The latter involves looking at the back of the wrist with the first closed; the user will hear the time, even if not wearing a watch.

However, there are also smartphone apps that do much the same thing, using the phone’s camera and touchscreen screen-readers such as Apple’s VoiceOver (iOS) and Android’s TalkBack (now part of the Android Accessibility Suite).

For example, Seeing AI – launched by Microsoft in July 2017 – is a free app that ‘narrates the world around you’. It allows the blind and visually impaired to read or identify short text, documents, products, currency and colours. As for OrCam, photographing people and adding them to the app’s database will enable the user to recognise them through facial recognition technology, and get an estimate of their age, gender and emotions. The app can even read handwriting, describe photos, generate an audible tone corresponding to the brightness of the user’s surroundings, and attempt to describe the scene, recognising obvious features like trees, houses, pets and furniture.

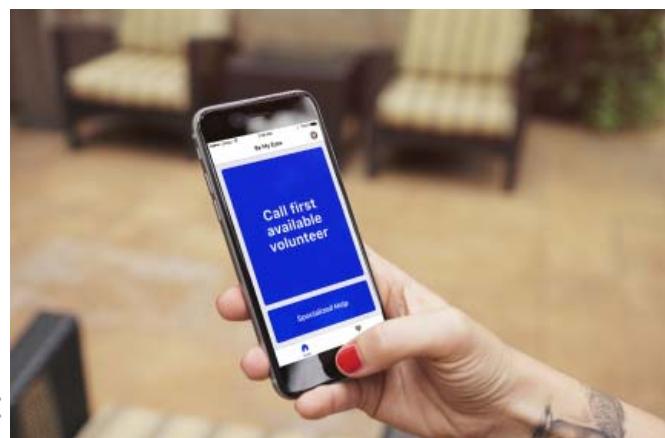
Currently, Seeing AI is only available for iPhones, and English is the only language supported. However, **Envision AI** is available on both iOS and Android, and



it can read text in over 60 languages. Developed by a start-up called Envision Technologies in the Netherlands, it won the Best Accessibility Experience prize at the 2019 Google Play Awards, considered the 'Oscars' for app developers. It can do most of the same functions as Seeing AI – and better in some cases – but it is not free, as there is a subscription fee following a month-long trial period. Likewise, Eye-D from India-based GingerMind Technologies has a free version with limited functionality, and a Pro version with a small fee of R125 and various in-app purchases, although reviews are mixed.

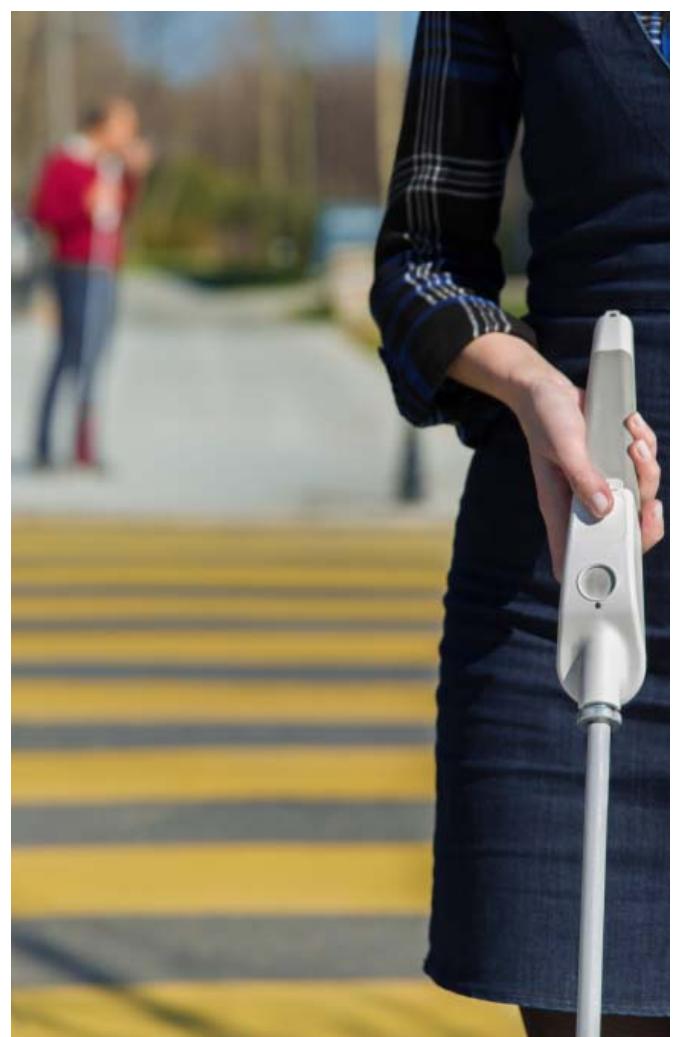
Google released its own version, called Lookout, on its Pixel 3 smartphone in October 2018, and it is now available on some LG and Samsung phones too, but the app can still only be downloaded by those with a USA-based account. It works slightly differently as the idea is to have the phone in a shirt pocket or hanging round the neck on a lanyard with the camera facing out, and auditory cues will be given as the person encounters things around them. The 'Home' mode, for example, will give a notification saying "couch three o'clock" if there is a couch on the person's right, while the 'Work & Play' mode looks out for things like elevators, computers and wastepaper bins. Apart from this Explore setting, there are 'Shopping' and 'Quickread' settings that scan barcodes, identify products and read text, like the other smartphone apps mentioned above.

BeMyEyes, developed in Denmark, is a free iOS and Android app that takes a different approach. Instead of



using artificial intelligence, it connects blind and low-vision people with sighted volunteers for visual assistance through a live video call. A volunteer might help a blind person, for example, to choose the best tie to go with a shirt, or identify the correct platform at the train station, or read a handwritten note. To date almost three million volunteers from over 150 countries have signed up, offering to assist in more than 180 languages. Since just over 150 000 blind and low-vision people are using the app, it can take more than a year before a volunteer is called for the first time, but it is heart-warming that there are so many people willing to help.

Another interesting offering is **WeWALK**. It is available on both Google Play and the iOS app store, but it is actually a device that can be fitted as a handle to the top of any white cane, turning it into a 'smart cane'. The main function is to warn the user of obstacles up to 160 cm away, from chest height and above, using an ultrasound sensor. The user is alerted by vibrations in the handle if, for example, there is an overhanging branch up ahead. The device can be controlled via either a touchpad or voice activation, with English and Turkish currently the only languages supported (WeWALK was designed by Kürşat Ceylan, a blind social entrepreneur from Turkey). By pairing the device with a smartphone, using Bluetooth and the WeWALK app, it can be integrated with Google Maps and Voice Assistant to get audible walking directions through the phone's speakers.



Google Maps itself recently became more useful to the blind and visually impaired, when a new feature began rolling out on 10 October 2019, which was World Sight Day. Users will now have the option of receiving more detailed voice guidance and new types of verbal announcements for walking trips. The app will let users know that they are on the correct route, the distance until their next turn and the direction they are walking in. Upon approaching large intersections, they will get a warning to cross with added caution. And if they accidentally leave their intended route, they'll get a spoken notification that they are being re-routed. Initially the feature was only available in English in the United States and Japanese in Japan, but support for additional languages and countries will be added soon.

A PhD student at Stellenbosch University is making his own contribution to assistive technology for the blind, hoping to make life easier for students who come behind him, as well as academics and professionals who need to interpret technical diagrams. Rynhardt Kruger is blind himself, having been born with a retinal degenerative disease, but he is also a computer boff, who decided he wanted to be a programmer when in Grade 10. He started his BSc at Stellenbosch University in 2009 and went straight on to Honours and Master's, becoming the first blind 'Matie' to obtain postgraduate degrees in computer science.

Until Rynhardt discovered his love of computers, he wanted a career in music, as he played both the piano and violin. So it's perhaps not surprising that he blended his gifts for his Honours project, when he developed a



Google Maps

computer-based reading system for musical scores. This was a cross-platform solution allowing blind musicians to access music downloaded from the internet using all major operating systems.

For his Master's project, Rynhardt developed software to navigate Second Life, an online virtual world. Second Life users create avatars for themselves, and interact with places, objects and other avatars. "Second Life is a virtual space for whatever you do in real life, and the technology is also used a lot in academia, for conferences," explains Rynhardt. "So I wrote a program that can be used by blind people to access Second Life, because it mostly relies on visual information – things that you can see on a screen, such as a forest clearing, or a gathering of people. I basically translated all those things into sound, through audible descriptions. My program worked well enough that I could use it to attend a virtual conference in a virtual world."

His PhD focuses on addressing a problem he encountered during his undergraduate degree. He explains that the only way for blind people to access flow diagrams, graphs and charts is to print them out on a tactile printer, and these machines are extremely expensive, so he had to make do with somebody describing diagrams to him. "But of course, if you think about the reason why people use diagrams, it's because a description isn't adequate – otherwise people would just have written descriptions in their papers! Sometimes it's necessary to know the relationships between elements in a diagram, or scale and so forth."

"So what I'm attempting to do is to use sound and a touchscreen to convey a shape of a technical diagram for blind people," he says. "Certain sounds would denote elements of the diagram, so they will be able to explore the diagram on the touchscreen, and get an idea of what it looks like by listening to the sounds."

He hopes to complete his PhD in 2020, and then continue working in the field of assistive technology.

"It's quite a passion for me," he says "Since I'm in computer science and I'm blind myself, I feel I have a deeper understanding of how assistive technologies could potentially work."

MOOC pursues dignity for disabled learners



The course explores the support that teachers require in order to meet the needs of children with visual, hearing or intellectual disabilities.

Based on the premise that inclusive education is only possible if teachers are supported and empowered to make the curriculum accessible to all learners, a University of Cape Town (UCT) Massive Open Online Course (MOOC) offers insight into how education systems can support and promote equity, equal access and dignity for learners with disabilities.

Called Disability Inclusion in Education: Building Systems of Support, the course explores the support that teachers need in order to be able to meet the needs of children with severe to profound hearing, visual or intellectual disabilities.

This dovetails with United Nations (UN) Sustainable Development Goal 4, which commits the global community to achieving inclusive and equitable education for all in a world where millions of children are currently unable to fully participate in schooling, but especially if they live with disabilities.

The MOOC is a product of the extensive research being conducted in the university's Teacher Empowerment for Disability Inclusion (TEDI) project, which aims to empower teachers to provide quality education for disabled learners. TEDI resides within the Department of Health and Rehabilitation's Disability Studies Division, in the Faculty of Health Sciences.

"The MOOC draws on our research within the TEDI project, placing the teacher at the centre of this change process, and looks at what support teachers need, and how they can be supported through education systems," said TEDI principal investigator Associate Professor Judith McKenzie, who also heads the Disability Studies Division.

Other than providing insight into how education systems can support teachers to promote equity, equal access and dignity for learners with disabilities, the MOOC also examines the specific potential needs of these children so that educators can ensure they get the same learning experience and consequent opportunities in life as their non-disabled counterparts.

The course, said McKenzie, runs for five weeks online on the Coursera platform, and is aimed at teachers, principals, policy developers, education officials and others concerned with expanding access to education and the full curriculum for learners with disabilities.

The three-year TEDI project is a partnership between UCT and the Christoffel-Blinden Mission (CBM), co-funded by CBM and the European Union. Other MOOCs have since been produced with the assistance of UCT's Centre for Innovation in Learning and Teaching.

The self-directed online courses are available to anyone with a computer or mobile device, an internet connection, and access to data to view or download the video lectures. The courses are not for university credit, so assessments are voluntary and participants who complete them can choose to pay for a verified certificate as proof of their achievement. Participants can also apply for financial aid if they cannot afford the certificate fee.

- Find out more about the Disability Inclusion in Education MOOC at: <https://www.coursera.org/learn/disability-inclusion-education>

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The TEDI project has developed a number of other online courses and also offers face-to-face short courses for educators, parents and caregivers supporting children with hearing, visual or intellectual disabilities. For more information, see the TEDI webpage: <http://www.dhrs.uct.ac.za/dhrs/divisions/disability/tedi>

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Chasing the rain in Jonkershoek

Retang Mokua tells us about her experience sampling a storm event to study streamflow-generation processes

It was a dark and stormy night. The wind whipped through the trees and sheets of rain lashed down on the tent.

It was almost midnight and I was ready. Gumboots on and sample bottles in hand, I stepped out into the storm and made my way to the river...

Never in my academic life have I imagined myself sitting in a small tent under the bushes with a torch, anxiously waiting for raindrops to hit the ground, but this is what we recently experienced in the Jonkershoek catchment, just north-east of Stellenbosch.

On 6 July 2019, SAEON's Dr Julia Glenday and two MSc students, Bongiwe Seleka and Kamohelo Mokoena, joined me as I set up camp in the Jonkershoek catchment to sample a heavy rainfall event as part of my PhD research on streamflow-generation mechanisms. We waited all afternoon, watching the clouds build up over the rocky mountains.

Just as it was getting dark, the rain started. We knew it would be a long night!

Our purpose

Mountain headwater catchments, such as those in the Jonkershoek Valley, are an important source of runoff, feeding rivers and dams. These catchments supply water downstream for domestic, industrial and agricultural use. Understanding how the rainwater is partitioned in these catchments – between water that stays caught on leaves and evaporates, water that reaches the ground and flows over the surface, water that enters the soil and rock layer and flows underground, or is stored and potentially used by plants – and how much reaches the stream is

fundamental for water resource management. To gain a better understanding of these processes for Jonkershoek, I wanted to see how the water chemistry changes as the river rises and falls in a storm. Water that has been stored in soils and rock can have different chemical signatures to rainwater.

The storm event sampling was done in two of the headwater subcatchments, Bosboukloof and Langrivier, which have different vegetation covers: pine plantation and fynbos.

Background: How can we tell which water comes from where and how much of it reaches the river?

Streamflow can be thought of as having two main components, namely surface runoff (quickflow or storm flow) and base flow, the latter fed by subsurface flows such as groundwater and soil water. The stream hydrograph – the variation in streamflow over time – can be separated into these components to detect their relative contributions to average annual outflow or to flows at different times and seasons.

Early pioneers of tracer-based hydrology have shown that water chemistry data can further help to differentiate streamflow into more specific components, identifying contributions from direct rainfall and surface runoff, soil water, and groundwater from different distinctive aquifers.

Chemical tracer studies have highlighted the importance of 'pre-event' water contributions during storm events – the water that has been stored in the catchment prior to the runoff event, such as groundwater and shallow subsurface water (soil water). This investigation aims to



The V-notch gauging weir used to measure streamflow in the Langrivier before and after the rain event.

determine which components contribute to Jonkershoek streams during wet and dry periods using tracer-based approaches.

Tracer-based approaches to hydrograph separation make use of naturally occurring environmental tracers such as stable isotopes of water ($\delta^{18}\text{O}$ and $\delta^2\text{H/D}$), major ions and dissolved silica, and composition indicators like electrical conductivity and pH. They provide an understanding of runoff-generation processes by revealing what portion of the stream water existed prior to a rain event, what portion was added to the stream during the event and where this water came from.

Commonly used tracers are selected for their conservative nature: they do not become completely altered as they travel through the water cycle, therefore they carry characteristics of their original source. The spatial and temporal variations in hydrochemical and stable isotope patterns can provide useful information on geographic water sources and pathways followed by rainwater in the catchment until it reaches the stream outlet.

Methods: Event sampling

The latest storm sampling fieldwork took place over two days, including an overnight event. To be able to perform the hydrograph separation, we collected water samples from groundwater boreholes, streams, springs and piezometers (shallow subsurface water). The base flow component was sampled a day before the expected rainfall event and again four hours before the rain started. At the start of the rainfall event, water samples from the streams and piezometer were collected every hour until peak flow, and later every two hours during the recession period.

Rainfall water samples were collected using sequential samplers equipped with 50 ml bottles assembled near the rain gauge to enable sample volume to be related to the rain intensity and rainfall period. Physico-chemical (EC, pH) measurements were also taken from all the sampled sources. Hydrometric measurements such as stream discharge, temperature and piezometer water levels were taken on an hourly basis.

After doing the laboratory analyses of the samples, the chemistry and stable isotope data from stream water, rainwater, soil water and groundwater will be incorporated into hydrographs to differentiate components of the stream over time during this rain event.

I plan to sample a summer storm later this year to compare the streamflow-generation mechanisms in different seasons. This will hopefully be a warmer affair!

Retang Mokua is currently pursuing her PhD at the University of the Western Cape under the Fynbos Node of the South African Environmental Observation Network (SAEON). This article is republished from the August 2019 issue of the SAEON newsletter and builds upon a previous article by Retang in the October 2018 issue, providing the background to her research: <http://www.saeon.ac.za/enewsletter/>



Retang installs the sequential rainfall sampler near the tipping bucket rain gauge.



Woer woers

How our African ancestors made sound in the Stone Age
By Sarah Wurz, Joshua Kumbani, Justin Bradfield and Neil Rusch

The Middle and Later Stone Age, which lasted from about 300 000 to 300 years ago in South Africa, was an important time for the African continent. During this period humans developed many different strategies to produce a variety of stone tools. They used fire as an engineering tool and to cook. As expert hunter-gatherers, they successfully inhabited many parts of Africa.

But one thing that's been missing from our understanding of this epoch is sound, noise or music. There's been very little research on the role of sound production during the Stone Age. That's very surprising since we know that the latter part of this period was an important one for the development of complex cognition, symbolic expression and social dynamics among human ancestors. So it stands to reason that groups which were communicating in complex ways might also explore sound for expression.

One reason to account for this lack of research may be that sound-producing instruments are usually made of organic materials which typically don't survive well, archaeologically.

We wanted to address this gap in the research. So we've established a working group to map and investigate Stone Age musical activities within Africa, incorporating ethnographic perspectives, knowledge gained from the in-depth study of various cultural groups.

One of our first projects has been to examine ancient versions of the strange disc-shaped object that South Africans colloquially know as a 'woer woer'. The woer woer ('whirr whirr' in Afrikaans) can be wound up between two pieces of string and released to produce the same kind of sound as a howling wind or a swarm of bees. Different versions exist in various parts of the world, known by different names.

Working with bone artefacts from archaeological sites in South Africa's southern Cape region, we've been able to show that some implements might have been used for sound production in the past.

This sort of research is important because it can shed light on human behaviour and the use of space. Some spaces may have been specifically selected for how well

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Translation by Zamantimande Kunene



A drawing of a broken bone artefact found at the Klasies River archaeological site in the 1960s was used as a reference for the replica woer woer on the left, while the replica on the right emulates a wooden 'spinning disk' collected from Bushmen in Namibia in the 1930s and archived in the Kirby Collection of Musical Instruments at the South African College of Music.

sound resonates and amplifies, perhaps to form part of rituals to induce altered states of consciousness or enhanced states of association.

Bullroarers and woer woers

The woer woer works on the same principle as another instrument, the bullroarer. This has been used for centuries in many societies to produce sound, chiefly during ceremonial occasions. When it's spun through the air it produces audible vibrations that travel for some distance.

At least two examples of woer woers made from perforated pieces of bone have been recovered from archaeological sites along the southern Cape coast, at Klasies River and Matjes River. Both date back between 5 000 and 10 000 years.

The Matjes River woer woer was recovered together with perforated bone pendants. Some of these 'pendants' bear a striking resemblance to bullroarers from other parts of the world. Bullroarers are used by the Bushmen and Aboriginal people and are also found in Late Palaeolithic sites in Denmark, Germany and Norway.

But how could we be sure what the southern Cape artefacts were or what they were used for? Simple: we headed to a recording studio.

MR 37 MR 205 MR 39 MR 40



Four bone pendants found at the Matjes River archaeological site, and the replicas made by the research team.

Using the actual bone artefacts wasn't possible – they are protected by heritage legislation – so we made modern bone replicas and spun them mechanically for a total of 15 hours. The resulting sounds were recorded in the Field Sound Studio, Cape Town. We also recorded where evidence of wear from use occurred.

The sound frequency of the objects we assumed were woer woers ranged from 52 to 200 Hz. These are bass sounds, resembling those in nature, such as bees humming.

The frequency range across the sample of pendant replicas varied from 55.5 to 250 Hz, which is comparable to that produced by bullroarers. The replicas produced a sustained pulsing sound that may be likened to the breaking of ocean waves, thunder or breathing. If played in a cave, such as the sites where the original artefacts were found, the aural affect would have been impressively magnified.

Armed with these data, we conducted a few more experiments. Our interpretation of these results is that one of the decorative pendants was used to produce sound, in the same manner as a bullroarer.

If this interpretation is correct it means that aerophones were used in the distant past in southern Africa. Aerophones produce sound by creating vibrations in the air when they are spun around their axes. They are known as some of the earliest musical instruments in the archaeological record.

Buzzing as ritual gateway

So, why were these ancient bullroarers used? It's possible that sound may be associated with burying the dead. The artefacts we tested from both sites were associated with human remains.

Matjes River has yielded the remains of 120 individuals. The site was certainly a sacred one within the landscape: it was a burial ground for thousands of years.

There are other possible uses, based on ethnographic knowledge from southern Africa. The Ju'hoansi San of Namibia associate the sound of the bullroarer, which they use in male initiation ceremonies, with mythical creators. /Xam Bushmen in the 19th century reported how they would use the bullroarer to manipulate bees.

Interestingly, people entering an altered state of consciousness report hearing a buzzing sound as part of their hallucinatory experience. Bees are also depicted in



The soundtrack recorded during spinning of the largest pendant replica reveals the rhythmic, pulsing nature of the sound. The section highlighted in orange in the top wave output is shown in more detail beneath.



Renée Rust



San rock art. These are believed to be associated with the altered state of consciousness shamans induced to enter the spirit world. When a woer woer or bullroarer is spun quickly a stroboscopic effect is produced, which may add to the hallucinatory experience.

This work not only aids our understanding of our ancestors' behaviour. It also suggests that it may be worth re-examining other bone artefacts whose true function may not yet be known.

- Listen to recordings of the replica woer woer and bullroarer at <https://theconversation.com/how-our-african-ancestors-made-sound-in-the-stone-age-121142>

The Klasies River archaeological site comprises a series of caves near the Klasies River mouth on the Cape south coast.

- Kumbani et al. 2019. A functional investigation of southern Cape Later Stone Age artefacts resembling aerophones. *Journal of Archaeological Science: Reports* Vol. 24: 693-711. <https://doi.org/10.1016/j.jasrep.2019.02.021>

Three of the authors are from the University of the Witwatersrand's School of Geography, Archaeology and Environmental Sciences, where Sarah Wurz is a professor, Joshua Kumbani is a PhD student and Neil Rusch is a research associate. Justin Bradfield is a senior lecturer with the University of Johannesburg's Palaeo-Research Institute.

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CURRICULUM CORNER

PHYSICS: GRADE 10

Sound waves; Pitch and loudness

LIFE SCIENCES: GRADE 12

Human evolution

SOCIAL SCIENCES: GRADE 4 & 5

Communication through time; Hunter-gatherers

Shooting for the stars

Using the world's largest and most energetic laser, scientists in the USA have been replicating the extreme temperature and density conditions inside stars to better understand the process of element formation within them.

The laser is known as the National Ignition Facility (NIF), and it's located at the Lawrence Livermore National Laboratory in California. The NIF building is so enormous that three football fields could fit inside it, and much of it is devoted to the laser and target area section. Here, almost 40 000 optics – including lenses, laser glass slabs, mirrors and frequency conversion crystals – precisely guide, reflect, amplify and focus 192 laser beams. A beam travels about 1 500 m in a few millionths of a second to arrive at a 3 mm-wide target in the centre of a 10 m-wide chamber. The tiny target is a gas- or ice-filled capsule typically containing hydrogen or helium isotopes, and when blasted with up to 1.8 million joules of energy it implodes, resulting in an extremely hot and dense core of plasma (freely moving ions and free electrons), where nuclear reactions occur.

The NIF was designed for experiments that create similar conditions – temperatures of 100 million degrees Celsius and pressures 100 billion times that of the Earth's atmosphere – to those found in a detonating nuclear device, with the aim of ensuring the safety of the USA's nuclear weapons stockpile. August 2019 marked NIF's 10th year in operation, and by then some 2 700 experiments, called 'shots', had been conducted by scientists working on nuclear weapons issues. However, about 8% of overall

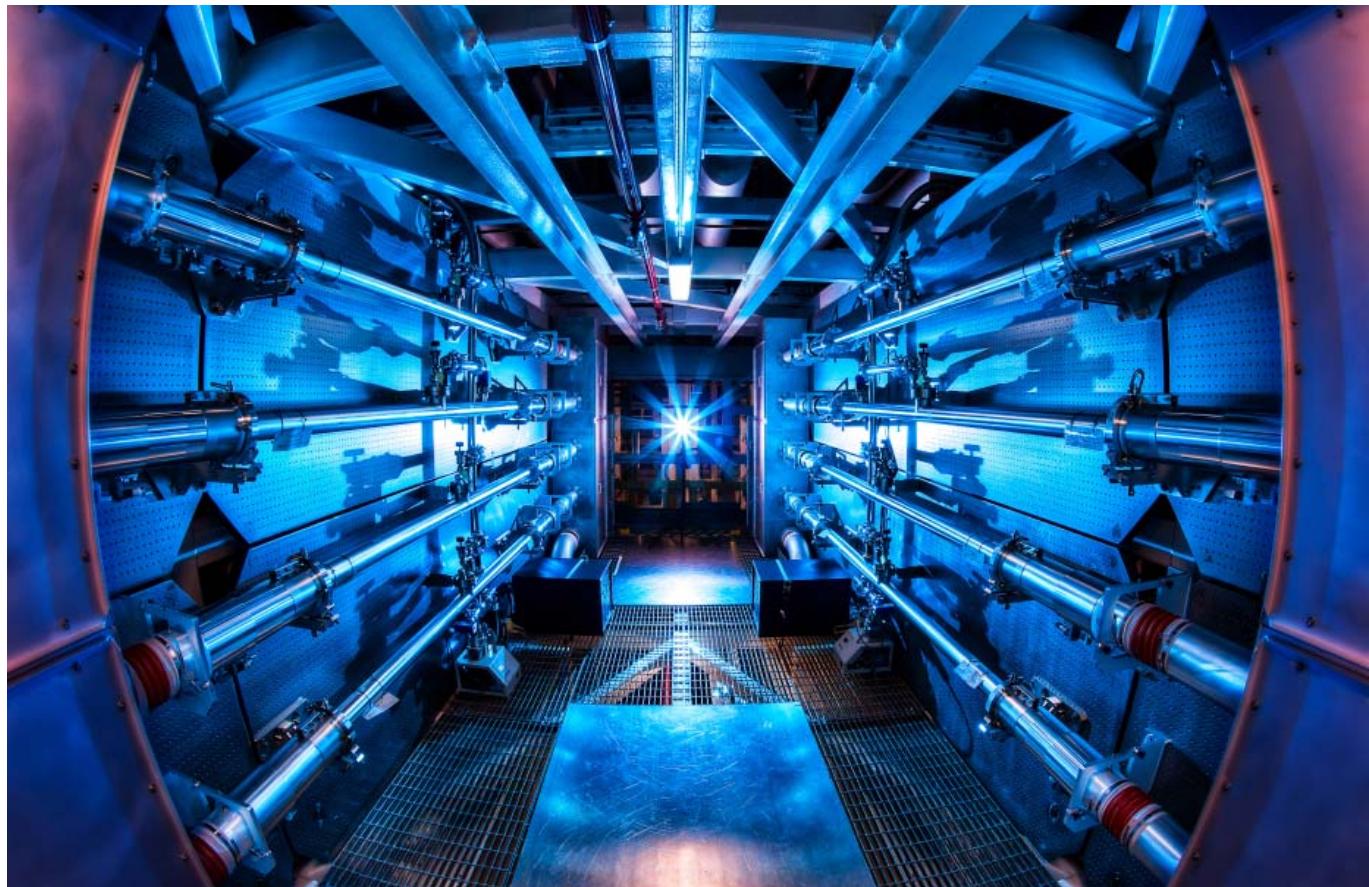


shot time is set aside for basic science experiments that probe the inner workings of stars, planets and materials.

Dr Maria Gatu Johnson, a research scientist at the Massachusetts Institute of Technology (MIT), is the principal investigator for a project examining stellar nucleosynthesis, or element formation, in the interior of stars. The American Physical Society (APS) recently named Dr Gatu Johnson the winner of the Katherine E. Weimer Award, which recognises outstanding plasma science research by a woman physicist in the early stages of her career. Her award acceptance lecture formed part



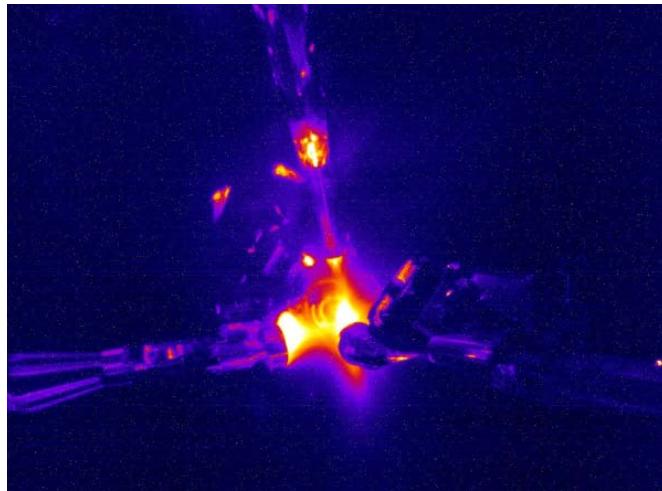
Technicians on a service lift inside the target chamber. The pencil-like structure on the right is the target positioner, which holds the tiny target.



of the APS Division of Plasma Physics meeting held in Fort Lauderdale, Florida, in October 2019. In it, Dr Gatū Johnson spoke about the ongoing NIF experiments to study fusion reactions of helium-3, a light helium isotope.

Previously, she had explained that these involve the 'proton-proton 1' chain of nuclear reactions at the beginning of the stellar nucleosynthesis cycle. In the core of the Sun and other stars, nuclear fusion converts hydrogen into helium, and a small amount of matter is turned into energy in the process.

"It starts with just the protons in the nucleus of regular hydrogen atoms," Gatū Johnson said. "They fuse to



'Shot-time' image from a NIF experiment simulating stellar nucleosynthesis, with $^3\text{He} + ^3\text{He}$ fusion reactions happening in the white-hot, dense centre.

The preamplifiers of the National Ignition Facility are the first step in increasing the energy of laser beams as they make their way toward the target chamber.

form deuterium (as one of the protons is converted to a neutron), and then deuterium can fuse with a proton to form helium-3. The helium-3 particles once produced fuse to form helium-4 (also known as an alpha particle), and generate two protons which will go through the cycle again."

"This is the most significant energy-producing step in the Sun – $^3\text{He} + ^3\text{He}$ reactions actually produce almost half the energy in the proton-proton 1 chain – so it's very critical to know the rate of that reaction."

Dr Gatū Johnson reported on how protons from the $^3\text{He} + ^3\text{He}$ reaction have been observed in these experiments at a range of conditions. "Surprisingly, the preliminary results show that at lower temperatures, relatively more protons are seen with higher energy than with lower energy," she said.

These results will allow scientists to add important constraints on theoretical calculations of this complicated reaction, and to estimate the probability of the $^3\text{He} + ^3\text{He}$ reaction happening. There will be one more round of experiments, currently planned for February 2020, where Dr Gatū Johnson plans to better characterise the temperatures reached in the star-like conditions.

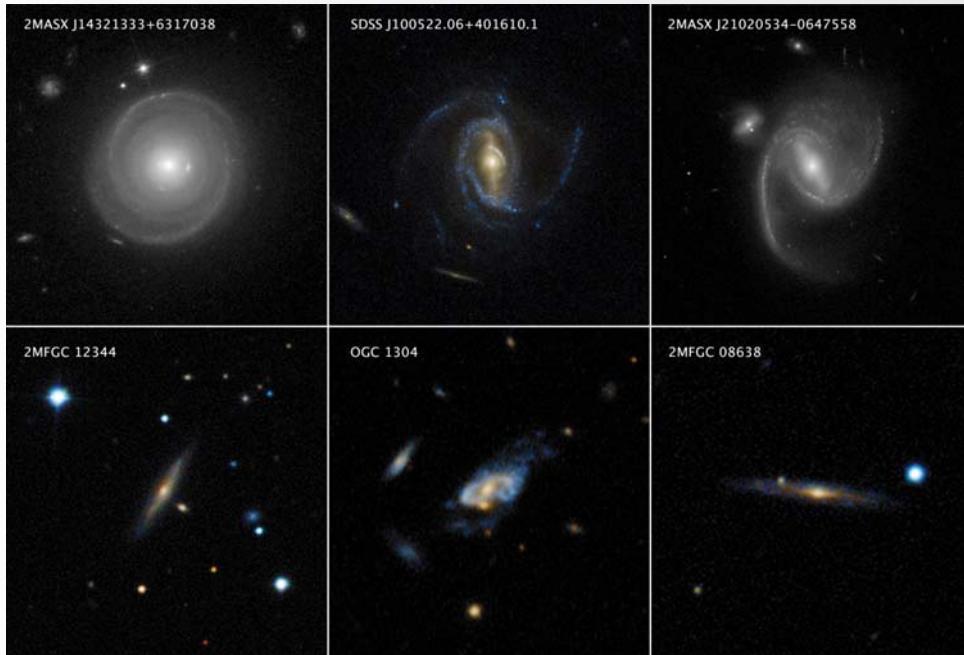
Adapted from press releases issued by the Lawrence Livermore National Laboratory (<https://lasers.llnl.gov/>) and the American Physical Society (<http://www.aps.org/>).

SALT observes super fast spirals

Astronomers using the Southern African Large Telescope (SALT) have measured the rotation rates of massive spiral galaxies

NASA, ESA, P. Ogle and J. DePasquale (STScI)

SDSS, P. Ogle and J. DePasquale (STScI)



The top row of this mosaic features Hubble images of three spiral galaxies, each weighing several times as much as the Milky Way. The bottom row shows three even more massive spiral galaxies qualifying as ‘super spirals’, which were observed by the ground-based Sloan Digital Sky Survey. The galaxy at lower right, 2MFGC 08638, is the most massive super spiral known to date, with a dark matter halo weighing at least 40 trillion times the mass of our Sun.

When it comes to galaxies, how fast is fast? The Milky Way, an average spiral galaxy, spins at a speed of 210 km per second in our Sun’s neighbourhood. New research has found that the most massive spiral galaxies spin faster than expected. These ‘super spirals’, the largest of which weigh about 20 times more than our Milky Way, spin at a rate of up to 570 km per second!

Only about 100 super spirals are known to date, and they are exceptional in almost every way. In addition to being much more massive than the Milky Way, they’re also brighter and larger in physical size. The largest span some 450 000 light-years compared to the Milky Way’s 100 000-light-year diameter.

A recent paper in the *Astrophysical Journal Letters* presents new data on super spiral rotation rates collected with the Southern African Large Telescope (SALT). Situated at the South African Astronomical Observatory (SAAO) field station near Sutherland in the Northern Cape, SALT is the largest single optical telescope in the southern hemisphere.

Theory suggests that super spirals spin rapidly because they are located within incredibly large clouds – or halos – of dark matter. Astronomer Vera Rubin pioneered work on galaxy rotation rates some decades ago, showing that spiral galaxies rotate faster than if their gravity were solely due to the constituent stars and gas. An additional, invisible substance known as dark matter must influence galaxy rotation.

A spiral galaxy of a given mass in stars is expected to rotate at a certain speed, but the team behind the recent paper found that super spirals significantly exceed the

expected rotation rate. What’s more, the most massive halo measured by the team contains enough dark matter to weigh at least 40 trillion times as much as our Sun. That amount of dark matter would normally contain a group of galaxies, rather than a single galaxy.

“It appears that the spin of a galaxy is set by the mass of its dark matter halo,” explains the paper’s first author, Patrick Ogle of the Space Telescope Science Institute in Baltimore, Maryland.

Yet given the amount of dark matter they contain, super spirals are actually underweight in stars. This suggests that the sheer amount of dark matter inhibits star formation. There are two possible causes: 1) Any additional gas that is pulled into the galaxy crashes together and heats up, preventing it from cooling down and forming stars, or 2) The fast spin of the galaxy makes it harder for gas clouds to collapse against the influence of centrifugal force.

Despite these disruptive influences, super spirals are still able to form stars. Although the largest elliptical galaxies formed all or most of their stars more than 10 billion years ago, super spirals are still forming stars today. They convert about 30 times the mass of the Sun into stars every year, which is normal for a galaxy of that size. By comparison, our Milky Way forms about one solar mass of stars per year.

- Ogle et al. 2019. A break in spiral galaxy scaling relations at the upper limit of galaxy mass. *Astrophysical Journal Letters*, 884 (1). DOI: 10.3847/2041-8213/ab459e

Q&A

with a nuclear physicist

University of Pretoria (UP) scientist

Dr Thabsile Thabethé says it's easier to succeed when you have role models who look like you

This interview was one of the #WomenofUP profiles posted on the university's website during August to celebrate Women's Month.

You're a nuclear physicist! Wow! What made you choose this career path?

During my first year at the University of Limpopo (Medunsa campus), an MSc student studying medical physics, Khombo Dumela, was my physics tutor and used to take a class of about 250 students for tutorials, and remarkably handle the whole session herself. I used to love the way she made us solve tutorial problems by ourselves and encouraged us to do all the problems without depending on her. In my eyes she was this smart young lady helping us with physics, the hardest subject known to man! This was really incredible to me and I really admired her intelligence. I also hoped that one day I would be the one helping other students with physics like her. That influenced my decision in continuing with physics up to Honours level.

But when I finished my Honours in physics, I wanted to do an Honours degree in financial mathematics. I was accepted at UP, but for some reason that I can't explain I decided to do an MSc degree in physics. Dr Dolly Langa, Professor Thulani Hlatshwayo and Professor Johan Malherbe were the people who made me become a nuclear physicist. I was star-struck by the fantastic work they were doing and I also wanted to be part of it.

What about nuclear materials? What do you do with them? What are you researching? Why are you interested in it?

My research focuses on studying nuclear materials used in nuclear reactors, specifically the silicon carbide (SiC) layer that is part of the coating layers for the fuel particles. These metal silicon carbide composites are used in a number of technological applications such as nuclear reactors, electronics (device fabrication) and aerospace engineering.



The SiC layer is used as the main diffusion barrier for fission products released when a nuclear reactor is operating. Fission is what happens when a nuclear particle's atom splits into two – it is also known as radioactive decay and produces large amounts of energy. The SiC layer fails to retain some of the fission products effectively. I focus on exploring possible metals which can be used as a sub-coating layer to assist the SiC layer in improving the shielding effect, which allows high burn-up and enrichment without degrading the SiC. This helps to develop safer nuclear fuel encapsulation technology. I find ways to improve the coating layers of the fuel particles in nuclear reactors to ensure the safety of the people working with the reactors.

How did you first get interested in science?

My Grade 10 teacher was an exceptional teacher. She made science fun and was always encouraging us not to give up. She used to do experiments with us using household goods like cleaning and washing agents. She would make sure that we were all hands-on and she would also guide us step by step until the end. At times, she would give us homework to come up with our own experiments using whatever was available at home. This was a great way of trying to help us to become creative. She moved back to India when I started Grade 11, but the love for science that she instilled in me didn't dissipate.

Why do you think so many girls, in particular, are put off by maths and science?

There are a number of factors and some of these are social. We grew up being told that science is hard, and we believe it. This can lead to a lack of self-confidence. When one fails to obtain the correct answer in a maths or physics problem, for example, there could be a belief that one is stupid and inadequate. Teachers and parents need to build the confidence of young girls by encouraging them and giving them opportunities to learn from their mistakes. They also need to help remedy any misconceptions young girls might have in a bid to build their logical and scientific reasoning.

Some young girls choose their subjects based on the kind of teachers they like. If they can connect to the teacher, they will take that teacher's subject. Girls respond better to encouragement and the teacher showing them that he/she believes in them. Enthusiasm for the subject from the teacher also plays a role in the way girls respond.

Another factor that influences subject choices is the career that one wants to pursue. Some girls will be discouraged from taking maths and science because they cannot think of themselves holding similar positions to the people they perceive are supposed to have those jobs. This can make certain career prospects seem unattractive. For example, some might not have seen a woman engineer or scientist. This can lead to a lack of interest in maths and science as they might think that careers related to these subjects are not for them. People will usually find it easier to succeed when there is a role model who 'looks like them' and comes from a similar background to them. Girls need to be exposed to such women to make it easier for them to envision themselves in a similar path to success.

Tell us a bit about your books for toddlers.

I was inspired to do these books by my two-year-old daughter, who really enjoys books when they are being read to her. Kids love learning something new and exciting, especially when it is related to numbers and figures. The books are meant to introduce physics and maths to babies and toddlers. The maths books aim to teach toddlers how to count, identify shapes, identify mathematical signs and relate them to science.

This will also provide them with a good foundation of maths so that they are able to grasp concepts like addition and subtraction. The physics books aim to help kids relate their daily activities in life to physics, learning a few physics concepts and not to shy away from asking questions. This in turn encourages kids to think and have enquiring minds.

The books are available on Amazon and Apple books, and available in South Africa from September 2019.

What would you like to see more of in terms of women in research?

I would love to see more young women join the science field and embracing it as their own playground. I really admire Professor Mamokgethi Phakeng (University of Cape Town Vice-Chancellor). She is an inspiration to all women in society. She is a living example that it is possible for women to infiltrate the science field. Also, women like Khombo Dumela really make a difference in the lives of a lot of students who are struggling to get by at universities, by encouraging them and helping them with their work.

Do you think your daughter will grow up to be a physicist too?

It's too early to tell, she may be tempted to because both her parents are physicists!

*Republished from University of Pretoria News, 13 August 2019:
www.up.ac.za/news*





Nicholas B. Pattinson

Non-invasive physiological measurements in wild animals

By Amanda Bourne and Susan Cunningham

Just like us, when animals experience stress, they show a physiological response in the body. This response can take many forms – an elevated heart rate, higher metabolic rate, an increase in circulating stress hormones (called cortisol in most mammals, including humans, and corticosterone in reptiles and birds) or, when heat stressed, a heightened risk of dehydration. Studying these responses in animals can tell us a lot about how much environmental stress animals can tolerate, helping to improve our understanding of animal biology and inform conservation management actions.

Traditional methods for measuring physiological responses to environmental stress can cause considerable disturbance, particularly when they involve repeated capture of individuals, along with taking samples of blood or tissue. For example, a common way to estimate energy expenditure and water use is by measuring the turnover of hydrogen and oxygen atoms in an animal's body as they are used during respiration and evaporative cooling. Typically, this involves capturing the animal, injecting it with heavy isotopes of hydrogen and oxygen (non-toxic 'doubly labelled water'), keeping it captive for a brief period, then releasing and later recapturing it. During this period, three blood samples are taken, and levels of heavy isotopes in the blood are measured over time. Likewise, estimates of stress, measured as

concentrations of stress hormones (glucocorticoids) circulating in the body, are often measured using blood plasma. Again, this involves capturing and handling study animals. It is possible that handling stress may obscure signatures of environmental stress, and finding less invasive ways to measure physiology in wild animals is therefore an important research priority.

Recently, the FitzPatrick Institute of African Ornithology's Hot Birds Research Project team, led by Dr Susan Cunningham of the University of Cape Town (UCT) and Professor Andrew McKechnie of the University of Pretoria (UP), took up this challenge. PhD student Amanda Bourne (UCT) and Honours student Emma Jepsen (UP) have been developing and testing non-invasive methods for measuring physiological responses in wild birds.

Amanda's research focuses on measuring metabolic rates and water use, and Emma's focuses on measuring stress. The research takes advantage of a habituated population of southern pied babblers, *Turdoides bicolor*, at Kuruman River Reserve in the Northern Cape, in collaboration with Associate Prof. Amanda Ridley, also affiliated with the 'Fitz'. The babblers are trained to weigh themselves on a portable scale in return for a small food reward, and they can be approached and observed by people consistently within 2–5 m without disturbance. Instead of injecting



Amanda's research relied on a habituated population of southern pied babblers. Instead of injecting the birds with doubly labelled water, she fed them beetle larvae injected with the isotope solution.

the birds with doubly labelled water, Amanda dosed her study birds by feeding them beetle larvae injected with the isotope solution. Instead of capturing the birds and taking blood samples, both Amanda and Emma collected faeces from the ground after the birds had excreted them naturally. These methods remove the need to touch the birds entirely.

In both studies, faeces provided an adequate substitute for blood as a source of body water (for the labelled water study) and stress hormone concentrations (faecal glucocorticoid metabolites used in the stress study). Derived measurements were sufficiently sensitive to detect meaningful biological patterns. And both non-invasive dosing and non-invasive sampling proved feasible in practice.



Amanda Bourne takes notes as the babblers weigh themselves on a portable scale in return for a small food reward.

The two methods were recently published, in *Functional Ecology* (Bourne et al. 2019, 33: 162-174) and *General and Comparative Endocrinology* (Jepsen et al. 2019, 276: 60-68). Together, these studies demonstrate that valuable information on the physiology of wild birds can be collected without imposing capture or handling stress – a step in the right direction for both improving animal welfare in science, and maximising the validity of measurements of responses to environmental stress under natural conditions.

*Amanda Bourne is a PhD candidate and Dr Susan Cunningham is her supervisor, a researcher and lecturer at the Fitzpatrick Institute for African Ornithology at the University of Cape Town. This article originally appeared in the July 2019 edition of UCT's Science Faculty Newsletter, *Science Matters*. <http://www.science.uct.ac.za/newsletters-1>*

The Hot Birds Research Project studies the behaviour and physiology of desert birds to understand and predict their responses to climate change. The researchers assess how birds cope physiologically as temperatures rise, the changes they make in their behaviour to mitigate exposure to heat, and the consequences of these behavioural and physiological changes for the birds' survival and reproduction. This information is used to infer which species in desert bird communities are most vulnerable to climate change, and why.

Climate change

Engela Duvenage reports on the implications for Africa's moths and butterflies

In coming decades, shifts in temperature regimes and rainfall patterns due to climate change will significantly influence where and in what numbers African species of moths and butterflies are to be found. This is according to a study completed at the Department of Conservation Ecology and Entomology at Stellenbosch University (SU), published in the journal *Ecological Modelling*. It shows that some species found in more temperate regions might experience a huge reduction in areas in which they can survive.

The paper puts forward a new process-based model that other researchers studying the effects of climatic changes on African butterflies and moths can readily use. The study was conducted while the lead author, Dr Madeleine Barton, was a postdoctoral researcher based in the department; she has since returned to Australia, where she is employed as a research scientist at the CSIRO. Her co-authors were the department's Professor John Terblanche and a former SU 'postdoc', Professor Brent Sinclair, who is now with the Department of Biology at Western University in Ontario, Canada.

"Compared to other regions of the world, we still know very little about how African species of Lepidoptera (which includes butterflies and moths) will respond to climate change," notes Prof. Terblanche, whose research focuses on the impact that climate change has on the distribution and population lifecycles of agricultural pests and disease-carrying insects such as tsetse flies. "The study of insects is important, because the agricultural sector is worried about how climatic changes will affect the distribution of known insect pests and others that pollinate crops. Ultimately, it influences our food security. Many insect species also carry diseases, and an expansion in their abundance or geographic range could have health implications for people."

According to Prof. Terblanche, the process-based climatic prediction model that Dr Barton developed is the first climatic model specifically designed to

incorporate how rainfall might interact with temperature to make more realistic predictions about the future of African butterflies and moths. Similar models have been developed for species from other regions of the world, such as Europe, North America and Asia. Dr Barton's model is open source and free to use by other scientists who have data available on the physiology and distribution of African species.

Dr Barton's model not only considers possible future temperature changes, but also the impact that changing rainfall patterns and droughts could have on insects. It was tested under current climatic conditions, as well as those predicted by the year 2050. The model was also put through its paces using data about the physiology and sensitivity to temperature and water availability of two endemic African species: *Busseola fusca* is a widespread agricultural pest affecting food security, while *Bicyclus anynana* is a well-studied butterfly.

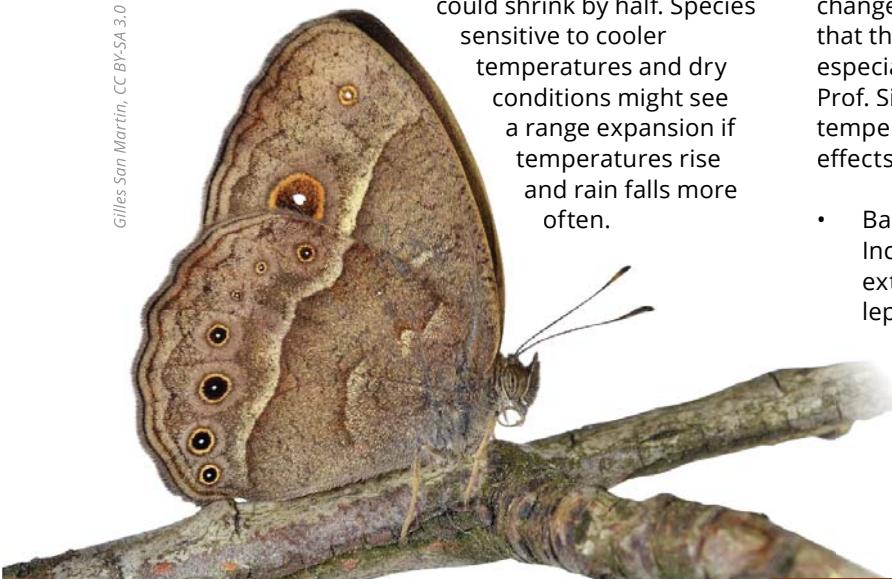
"For more accurate predictions, it is better to include temperature changes along with the availability of water, because these elements influence the survival of species in different ways. The distribution and population performance of an insect across the continent under climate change will depend on its physiological ability to tolerate specific conditions," explains Dr Barton.

Ukushintsha kwesimo sezulu kuzothikameza ukusabalala nobuningi bezinhlobo ezahlukene zezimvemvane. Lokhu kungaba izindaba ezinhle kuba limi, ngoba ezinye zalezimvemvane zecekela phansi izitshalo. Noma kunjalo, ezinye izinambuzane zizoyithatha indayo yalezimvemvane, ziqhubekе zicekele phansi lezizitshalo.

Translation by Zamantimande Kunene

The researchers found that higher temperatures and changing rainfall patterns could decrease the distribution of certain African butterfly and moth species currently widely occurring across the continent by up to 72%. The range of species of others that cannot withstand higher temperatures, such as the potentially damaging maize stem borer (*Chilo partellus*), could shrink by half. Species sensitive to cooler temperatures and dry conditions might see a range expansion if temperatures rise and rain falls more often.

Gilles San Martin, CC BY-SA 3.0



Species in the northern parts of Africa are predicted to move towards coastal and higher-lying areas to escape the evolving harsh climates, while the range of those in the southern parts of Africa are likely to shrink.

"When we look only at temperature, it seems that species in the tropics are most sensitive to climate change. However, when using our models, it shows that these impacts also extend to temperate regions, especially when precipitation patterns change," explains Prof. Sinclair. "These interactions between extreme temperatures and drought in the future could have big effects on insects in Africa and elsewhere."

- Barton, MG, Terblanche, JS & Sinclair, BJ 2019. Incorporating temperature and precipitation extremes into process-based models of African lepidoptera changes the predicted distribution under climate change. *Ecological Modelling* 394: 53-65. DOI:10.1016/j.ecolmodel.2018.12.017

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Soapbox Science



Visitors to Cape Town's Victoria & Alfred Waterfront may have been a little surprised to find a bunch of women in white coats standing on their 'soapboxes'* and holding forth on a range of scientific topics, but they soon gathered round to hear what they had to say. The occasion was the first Soapbox Science event to be held in South Africa, and it took place on a sunny day on the last Saturday in September, when the waterfront was abuzz with people.

Soapbox Science started in 2011 in London – inspired by Speakers' Corner in Hyde Park – but has now spread around the world, with 42 events held in 2019. It's a novel platform for promoting women scientists and the science they do, while also fulfilling a public outreach function. Events take place over three hours, with each group of speakers taking to their soapboxes for an hour to share their science and interact with bystanders in a fun but informative way.

The Cape Town event was coordinated by Dr Lucia Marchetti, a postdoctoral astronomy researcher in a joint position at the University of Cape Town (UCT) and the University of the Western Cape (UWC). She participated in a Soapbox Science event in London in 2015, and enjoyed it so much that she wanted to share the experience. Nine speakers took part on the day, drawn from more than 50 applications from around South Africa.

Dr Edina Amponsah-Dacosta, a postdoctoral researcher at UCT, used a creative roadmap to show what a vaccinologist does, how vaccines are made, and the long and winding road in bringing a new vaccine to market, involving diverse stakeholders. "I discussed how vaccines work to protect individuals and communities from contracting potentially fatal diseases, and how this has led to a remarkable decline in the burden of several of these diseases – such as polio and measles – globally, over time. My core message, however, was on the importance of viewing the decision to vaccinate as a matter of social solidarity or *ubuntu*." She explained that this is because the more people are vaccinated, the better chance we have of reducing the spread of vaccine-preventable diseases, in so doing protecting the most vulnerable populations within our community from the devastating effects of these diseases.

* A soapbox refers to a raised platform on which one stands to make a speech. The term originates from the days when speakers would elevate themselves to be seen in a crowd by standing on a wooden crate, previously used as packaging for transporting soap or other goods from the manufacturers. The term is also used in situations when someone expresses strong opinions about a particular subject. The concept was popularised at Hyde Park's Speakers' Corner, where people have gathered since the mid-1800s for speeches and debates on politics, religion and other topics.



Associate Professor Liesl Zühlke had plenty of volunteers for an on-the-spot echocardiogram. She is the Director of the Children's Heart Disease Research Unit and a Paediatric Cardiologist at Red Cross War Memorial Children's Hospital in Cape Town. "My research is to improve outcomes of children with heart disease by conducting family-centred and community-accountable research," she explains. "Congenital heart disease is the number one birth defect, the most common cause of death under a year in developed countries, and it kills more children than all childhood cancers combined. It is about 1:100 children and can be treated and managed in over 95% of cases, if diagnosed in time."



Edith Phalane, a PhD candidate at North-West University, gave new meaning to the expression 'wearing your heart on your sleeve' when she spoke about her research work on cardiovascular health, using an innovative method of display. "I shared with the public on how to keep your heart happy and keep the doctor away," she says, pointing out that it starts with living a healthy lifestyle by eating more fruits and vegetables, reducing fatty food and salt intake, avoiding tobacco use, as well as exercising. "It is important for the public to be informed and make the right choices," she says.

Mieke du Plessis, a PhD candidate at UCT, spoke on 'Bugs and brains: how your microbes influence your mind'.



Dr Kerryn Warren, a postdoctoral researcher in archaeology at UCT, related her experiences as an 'underground astronaut', excavating out the fossil remains of *Homo naledi* in the Rising Star cave system in the Cradle of Humankind. She explained the challenges of reaching the Dinaledi Chamber, which requires crawling through narrow rock passages and negotiating a steeply sloping chute, and discussed the size and shape of hominin skulls, as well as what they reveal about intelligence, diet and locomotion.



Dr Natasha Ross from UWC's Department of Chemistry noted that her area of expertise is electroanalytical chemistry, and her research focuses on finding more cost-effective and efficient photovoltaic cells and lithium ion batteries. She highlighted the sustainability of renewable energy sources like solar and wind energy, as well as their role in meeting targets to reduce greenhouse gas emissions that contribute to climate change. She used a simple model to explain how photovoltaic cells in solar panels generate electricity.



Sunscreen from cashew nut shells?

A team of international scientists has found an environmentally friendly way of producing potential sunscreens by using cashew nut shells, a waste material.

So-called 'green chemists' from the University of the Witwatersrand, along with colleagues from universities in Germany, Malawi and Tanzania, are working on techniques to produce useful compounds from wood and other fast growing non-edible plant waste, through a chemical process called xylochemistry (wood chemistry).

Using cashew nut shells, the team has produced new aromatic compounds that show good ultraviolet (UV) absorbance. These compounds could potentially be applied to protect humans and livestock, as well as paints, polymers and coatings, from the sun's harmful rays. The research was published as the cover article of the *European Journal of Organic Chemistry* in August 2019.

UV rays are damaging to most materials, leading to the discolouration of dyes and pigments, weathering, yellowing of plastics, and loss of gloss and mechanical properties. In humans and animals, solar UV radiation can cause sunburn, premature ageing and even the development of potentially lethal melanomas.

To mitigate UV damage, both organic and inorganic compounds are used as UV filters. Ideal organic UV filters display a high absorption of UVA (in the wavelength range 315–400 nm) and UVB (280–315 nm). One important family of UV absorber molecules are derived from aromatic compounds known as phenols, which contain a hydrogen-bonded hydroxyl group that plays an important role in the dissipation of the absorbed energy.

For example, the organic compound 2-hydroxy-4-methoxybenzophenone, also known as oxybenzone or Benzophenone-3, is a common ingredient in human sunscreens, and has also been added to plastics to limit UV degradation. However, it has been shown to cause damage to marine corals in laboratory experiments, and has been detected in freshwater fish from rivers around the world. As a result, there is growing attention from



regulatory bodies and stricter regulations are being enforced on the production of sun-filtering products.

"With the current concerns over the use of fossil resources for chemical synthesis of functional molecules and the effect of current UV absorbers in sunscreens on the ecosystem, we aimed to find a way to produce new UV absorbers from cashew nut shell liquid (CNSL) as a non-edible, bio-renewable carbon resource," says Professor Charles de Koning, of the Wits School of Chemistry. "Cashew nut shells are a waste product in the cashew-farming community, especially in Tanzania, so finding a useful, sustainable way to use these waste products can lead to completely new, environmentally friendly ways of doing things."

The team has filed a patent application in order to commercialise the process in South Africa. Further research is needed to investigate the human health aspects of the cashew-derived compounds before they are used in sunscreens.

*Issued by Wits University, 15 August 2019:
<http://www.wits.ac.za/news/>*

Marine sciences curriculum

If all goes according to plan, learners at schools around the country may have the option of taking Marine Sciences as a school subject within a few years. On 19 July 2019, the subject's Curriculum and Assessment Policy Statement (CAPS) for Grades 10 to 12 – developed by the education team from the Two Oceans Aquarium in Cape Town – was gazetted for public comment.

Some revisions would likely be made on the basis of comments received, but the curriculum as gazetted covers the following four strands, all of which are to be taught in each school term.

- **Oceanography**, including marine geology, geography, chemistry and physics, explaining:
 - the sea floor and sediments, together with the structure and origins of coastlines and how these change over time
 - the chemical composition and properties of sea water, and the effects of pollutants on ocean life
 - the ways in which the ocean acts as a driver of weather and climate
 - the waves, tides and currents
- **Marine Biology**, investigating the classification, fundamental biology, evolutionary processes, marine biodiversity and the adaptation of organisms to their environments
- **Ecology**, exploring ecosystems such as rocky shores, kelp forests and sandy beaches through ecological concepts, including nutrient cycles and food chains
- **Humans and the Ocean**, highlighting:
 - marine careers
 - marine protected areas (MPAs) as a model for sustainably managing ocean resources
 - the harvesting of renewable and use of non-renewable ocean resources

- the importance of research in understanding the ocean and the effects that human activities and practices have on the ocean and larger global patterns (for example, climate change and ocean acidification).

During 2019, Marine Sciences was introduced as a Grade 10 pilot subject at three schools – South Peninsula High and Simon's Town School in the Cape Town area, and Gansbaai Academy in the Overberg area – working in close partnership with the Two Oceans Aquarium.

The subject was offered as an 'after-school extra' on two or three afternoons per week, depending on the school's preference, and learners from neighbouring schools and surrounding areas could attend too, subject to their successful application and a supporting letter from their own school.

At South Peninsula High, for example, 21 learners participated in the 2019 programme, and 11 of these were from four other schools. Simon's Town School had 24 learners signed up, but all but three of these were from the home school, which has a particularly strong marine focus. The Lawhill Maritime Centre forms part of the school, offering a Maritime Studies course comprising two specialised subjects – Maritime Economics and Nautical Science – for learners in Grades 10 to 12. Asked in October how the Marine Sciences programme was going, teacher Asheeqah Davis replied: "I'm having a blast with the kids – they're thoroughly enjoying it!"

In 2020 the official pilot will begin, with the Grade 10s of 2020 taking Marine Sciences as one of their matric subjects in 2022. The three existing schools and at least three other schools, all in the Western Cape, have confirmed that they will be offering it as an 8th subject, with lessons during school hours.



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Two Oceans Aquarium

Books

Orca:

The Day the Great White Sharks Disappeared

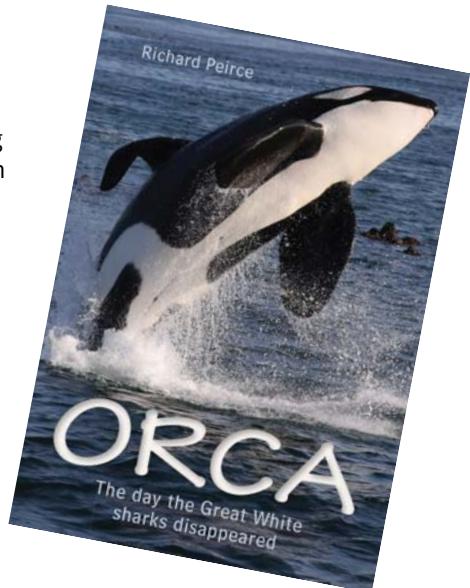
By Richard Pearce. 144 pp. Struik Nature. R190

Anyone who has heard of Gansbaai and the neighbouring village of Kleinbaai on the Overberg coast will likely know that the area is a popular shark cage-diving destination – in fact, it's widely considered the 'great white shark capital of the world'. A steady stream of tourists get shuttled in from Cape Town, 2½ hours' drive away, to take a boat trip out to Shark Alley, a channel between two small islands inhabited by seals and penguins. A 'great white sighting' was virtually guaranteed – until, that is, some killer whales showed up and chased the sharks away. That's the theory at any rate, and it's backed up by circumstantial evidence, such as mutilated carcasses of sharks that washed up on local beaches both here and in Cape Town's False Bay, and sightings of two killer whales, named Port and Starboard because of the way their dorsal fins had bent over to one side.

The book is a highly readable account of these events, and the impact on the cage-diving operators who employ some 200 people. It manages to convey a sense of drama, and captures the mixed emotions of various people in the area. The short chapters and frequent scene changes ensure that the pacing never lags, and impart a style and

structure that bring to mind a long-form article. Indeed, given the book's A5 format, generous line spacing and large photographs on most pages, the book could easily be read in an afternoon.

A short section at the end of the book is dedicated to general information on killer whales – more correctly called orcas after their species name *Orcinus orca* – as well as great white and bronze whaler sharks. The threats posed by longline fishing and abalone poaching are also addressed, and there's a double-page postscript providing an update as of mid-2019.



The Last Elephants

Compiled by Don Pinnock and Colin Bell.

488 pp. Struik Nature. R490



This 'coffee table book' combines spectacular photography with chapters written by more than 40 people involved in elephant conservation in some way, from rangers and scientists to activists and safari lodge owners. It came about when the compilers – a former editor of *Getaway* magazine and the co-founder of Wilderness Safaris – became aware of the results of the Great Elephant Census 2016, which showed that elephant numbers in Africa had fallen to

450 000 from an estimated three to five million a century ago. They sent out an email requesting contributions from people 'on the ground', and had more responses than they had dared hope for. Such was the quality of the writing and photography, and the stature of the contributors, that they needed to do the work justice, so no expense was spared in producing the book. The fact that the Foreword is written by Prince William is testament to its high standard.

Quick ID Guide:

Wild Flowers of the Cape Peninsula

By Hugh Clarke and Corinne Merry.

160 pp. Struik Nature. R130

This handy little book is perfect for those who want to identify flowers without getting to grips with identification keys, which require an understanding of characteristics like leaf type, shape and arrangement. This is because the flowers here are organised purely on the basis of colour, from lilac to various shades of purple, pink, red, orange, yellow, green and white. A colour tab on the edge of each page means that the appropriate colour grouping can be located before even opening the



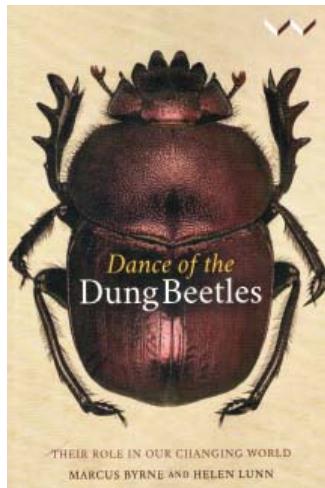
Dance of the Dung Beetles:

Their Role in our Changing World

By Marcus Byrne and Helen Lunn. 228 pp. Wits University Press. R320.

Thanks to frequent coverage on TV news and in other media, many of us are aware of the somewhat bizarre dung beetle experiments conducted by Marcus Byrne and colleagues over the years. As explained in this book's introduction, the Wits University professor and a group of scientists from South Africa, Sweden, Australia and Germany have got together annually since 2003 for a working holiday of 'playing with dung beetles'. Sometimes this has involved fitting the beetles with tiny boots or caps, or shining different coloured spotlights on them, or giving them fake dung balls, but in the process the scientists have made some remarkable discoveries about the beetles' behaviour and ability to navigate using light from the sun, moon and stars.

So by their own admission, the authors knew a lot about dung beetle orientation when they set out to write this book, but not so much about some of the other topics



tackled, from Egyptology to evolutionary biology. Based on their research, they were able to use dung beetles to trace the history of science over the last few thousand years, and also explore their cultural importance through the ages. Victorian ladies, for example, liked wearing dead ones as earrings, while the Kamba people of Kenya see the dung beetle as a cursed individual, doomed to roll his dung ball forever because he refused to prepare food for his dying mother.

There are interesting accounts of Charles Darwin's observations on dung beetles, their use as a biocontrol agent to deal with fly plagues associated with cattle farms in Hawaii and Australia, and their ecological role on the Serengeti plains. Some parts are very amusing, but given the in-depth treatment of the topics, the book will appeal mostly to regular readers of the history and popular science genres.



book. From there, the flower can be easily found with the help of a clear photograph, a brief description of the plant and its habitat, as well as information on flowering season. Both English and Afrikaans common names are provided where possible, along with the scientific name and family.

First published in 2007 as *Common Wild Flowers of Table Mountain*, the book was revised to include Silvermine and Cape Point, which meant the number of flowers featured increased from 208 to 360. Of course, this doesn't cover

all flowers found in the area – there are more than 2 285 plant species on the Cape Peninsula, so the authors selected only those that produce attractive, eye-catching and easily seen flowers.

The book begins with a section on walking routes, reflecting the fact that the authors are keen hikers, and there are three attractive maps for these routes, as well as a page on mountain safety.

Field Guide to Wild Flowers of South Africa

By John Manning. 488 pp. Struik Nature. R390

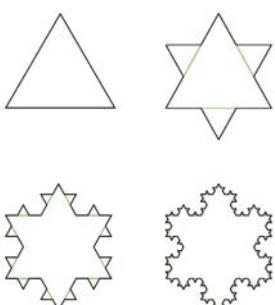
This is an update of the first edition, published a decade ago. It covers more than 1 100 species, focusing on the country's most common, conspicuous and 'showy' plants, which have been assembled in 10 groups of families with characteristics in common. The identification keys are relatively easy to use, thanks to the accompanying explanatory diagrams, and the short but detailed species descriptions are supported by useful photographs, distribution maps and flowering season charts.



Weeks of hard work on science projects paid off for female learners who bagged the biggest prizes at the Eskom Expo International Science Fair in September. Both the Top Senior and Top Junior Scientists were female, as were the winners of the Siemens Grand Prize and the four Eskom Special Awards, among others.

The Top Senior was Iqra Faki, a Grade 12 learner from Star College Sybrand Park Girl's High in Cape Town. Iqra won a R75 000 cash prize and was also awarded the Meiring Naudé Award for the most inspiring project. Her project, 'Fractal exploration: The 3-dimensional Koch snowflake', aimed to examine mathematical trends and noticeable properties for the surface area and volume of the three-dimensional Koch snowflake.

Interviewed by Joanne Joseph on Radio 702's Afternoon Drive show, Iqra explained her project in simple terms. "I used the principles of the Koch snowflake to create a three-dimensional version. The Koch snowflake starts off as an equilateral triangle, and then you divide the sides by three, and you add an equilateral triangle a third of that length to each side, and then it carries on," she said. "So basically what I did was instead of starting off with



The Koch snowflake is a fractal – a shape made of parts similar to the whole. It begins with an equilateral triangle and then replaces the middle third of every line segment with a pair of line segments that form an equilateral bump. The snowflake encloses a finite area, but has an infinite perimeter.

an equilateral triangle, I started off with an equilateral tetrahedron, and then divided the measurements by three and added it to each face. And using that shape I proved that the surface area and volume is finite, but the perimeter and number of vertices is infinite."

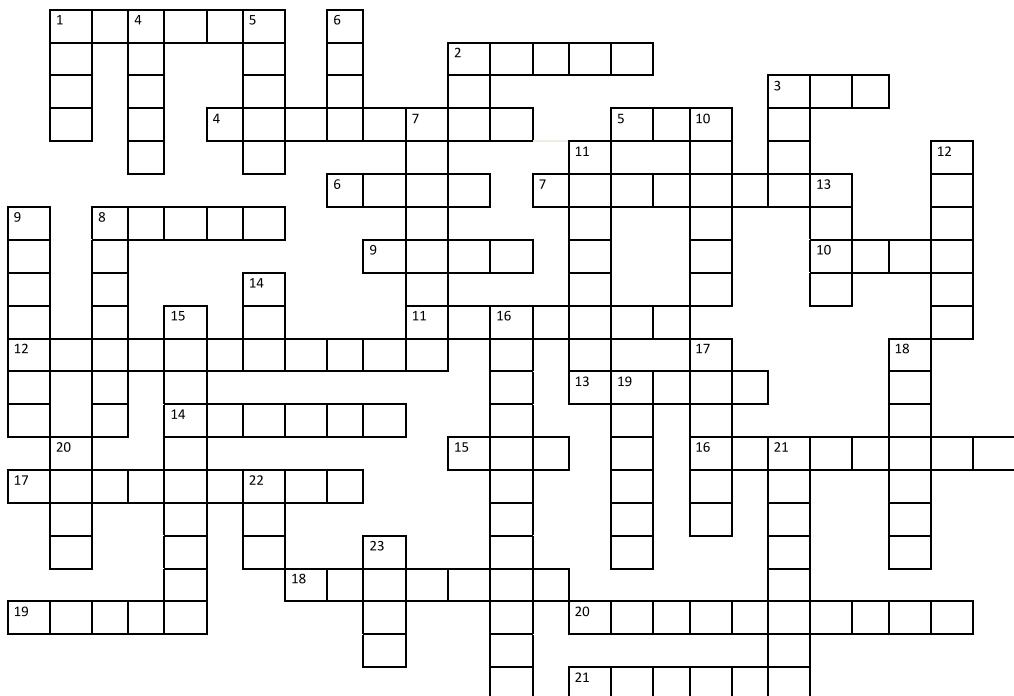
The Top Junior scientist – winning R50 000 – was Abigail Bloem, a Grade 9 learner from Eunice Secondary School in Bloemfontein. Her project, 'Bright solution', aims to prevent traffic light failures with a renewable energy (wind and solar) back-up battery system, together with a fault detection system that uses Arduino coding to report faults instantly to technicians.

The Siemens Grand Prize winner was Pinky Jiyane, from Ongoye Secondary School in Kwazulu-Natal North Coast, for her project 'Ultra smart meter'. The meter allows electricity to be loaded by sending a message from a smartphone, rather than having to punch in numbers. The balance left on the meter could be checked on the phone, and alerts would be sent when units drop below 10 units. Jiyane will receive a three-and-a-half-year technical apprenticeship at Siemens in Berlin, Germany, and a job offer thereafter.

Eskom's four Special Awards allowed Iqra Faki to add to her winnings, as Best Female. The Best Development award went to Maluta Gcabashe from H.P. Ngwenya Primary School in Central KwaZulu-Natal for her project 'Creating a low-dust, environmentally friendly chalk', while Miné Steenkamp from Hoërskool Douglas in Kimberley earned Best Innovation for her project 'Fighting crime with malaria-fighting drug'. Tripti Patel from Zinniaville Secondary School in Bojanala got Best Energy for her project 'Affordable warmer'.

Test your knowledge

Most of the answers can be found in this issue of *Quest*.



Across

- The shape describing most galaxies
- A pressure wave that we hear
- Our galaxy is the Milky ___
- The international study on neuromuscular disease will use this approach
- The hearZA app is this type of hearing test
- An acronym for a free online course
- These birds weigh themselves in exchange for food
- Intellectual disabilities result from ___ damage
- Describes a partial ossicle implant
- The species name for a killer whale
- The study of interactions between organisms and with their environment
- Ancient instruments spun through the air to make sound
- A device on glasses that reads aloud for visually impaired people
- Cortisol is a ___ hormone
- An otorhinolaryngologist is commonly called an ___ specialist
- The Fitzpatrick Institute's research programme on desert birds
- The prosthetic hand developed at UKZN
- A shape made of repeating parts of the same shape
- Lepidoptera are butterflies and ___
- The theme of this issue of *Quest*
- Nuclear fusion converts hydrogen into this element in stars

Down

- Acronym for the largest telescope in the southern hemisphere
- The chemical formula of silicon carbide

QUEST MATHS PUZZLE NO. 51

Starting in the bottom left corner and moving either up or right, adding up the numbers along the way, what is the largest sum you can make?

2	3	5	4	1
3	2	4	3	4
5	1	3	5	2
3	3	2	3	1
1	4	2	4	4

Answer to Maths Puzzle no. 50: 375 bubblegum blocks (70 chocolate cake slices and 55 fudge pieces)

WIN A PRIZE!

Send us your answer (fax, e-mail or snail-mail) together with your name and contact details by 15:00 on 14 February 2020.

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