

# SCIENCE FOR SOUTH AFRICA Quest

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**Terrestrial microbes  
of Antarctica**

**Journey to  
the sea ice**

**Biobank for wildlife  
research and conservation**

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**Editorial enquiries**

The Editor | e-mail: Quest-Editor@assaf.org.za

**Advertising enquiries**

Barbara Spence | Avenue Advertising  
 PO Box 71308, Bryanston 2021  
 Tel: (011) 463 7940 | Cell: 082 881 3454  
 e-mail: barbara@avenue.co.za

**Subscription enquiries and back issues**

Tsepo Majake | Tel: (012) 349 6645  
 e-mail: tsepo@assaf.org.za

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# Embracing the cold

In mid-February, as COVID-19 infections were starting to accelerate around the world, American researchers revealed the first 3D structure of the SARS-CoV-2 spike protein, which allows the virus to gain entry into cells. This was achieved with cryoelectron microscopy (cryo-EM), a technique that involves flash-freezing samples in solution and then bombarding them with a beam of electrons to produce thousands of images, which are stitched together with software to reconstruct the 3D shape. Three scientists were awarded the 2017 Nobel Prize in chemistry for developing the technique, which has made such advances in recent years that it now allows detailed imaging of biomolecules, viruses and cell organelles.

This is just one of many ways in which freezing temperatures are used in science and technology. For example, modern radio telescopes have cryogenic receivers that are cooled with liquid nitrogen or helium to increase detection sensitivity. If this is not done, the thermal noise generated by electrons and atoms in the electronic circuits and other materials would swamp the faint signal from space.

The term cryogenic (derived from kryos = Greek for cold, and genic = producing) is generally considered to relate to temperatures between  $-150^{\circ}\text{C}$  and  $-273.15^{\circ}\text{C}$ , or absolute zero, where there is no heat at all, nor any motion of atoms and molecules. Cryogenics includes both the study of how to produce these very low temperatures, and how materials behave at such temperatures.

Cryogenics has a variety of applications in industry too. Cryogenic hardening involves treating steels and composites with

cryogenic temperatures to improve corrosion resistance, while cryogenic grinding – also known as cryomilling – cools materials to make them brittle and easier to grind. The latter is widely used to manufacture or recycle plastics and other polymers, even turning old car tyres into rubberised playground surfaces or sport turfs. It is also used to produce fine powders such as spices and coffee in the food-processing industry, which also relies heavily on cryodesiccation, more commonly known as freeze-drying.

Of course, we use freezing to preserve our food too, and chill our drinks with blocks of ice. In South Africa, ice doesn't occur in the natural environment in large quantities for very long, but many other parts of the world experience months of icy landscapes, much like those in Disney's Frozen movies. The frozen parts of the planet make up the cryosphere, which plays a vital role in regulating global climate, but is itself severely threatened by climate change.

In this issue of *Quest*, we focus on ice and freezing temperatures, and present some scientific endeavours and technological innovations in this field.

**Sue Matthews**  
*Quest* Editor



Lesi siqephu se *Quest* sibheka iqhwa nokwehla kwamazinga okushisa, kwimvelo Kanye nase lebhu.

*Translated by Zamantimande Kunene*

# It's FREEZING out there!

Jaime Chismar, CC BY 2.0

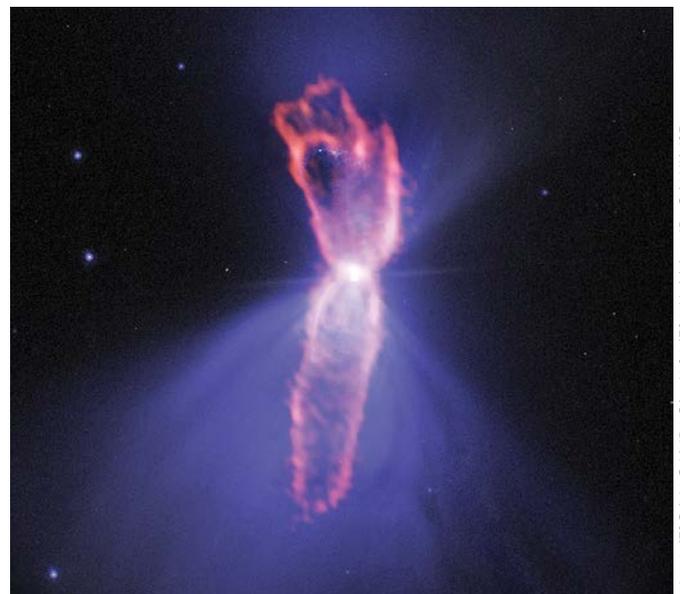
Our winters may bring some chilly mornings, but these are relatively warm compared to low temperatures that occur elsewhere. *Quest* takes a look at some of the coldest places.

## Coldest place in the universe

The Boomerang Nebula, some 5 000 light years from Earth in the constellation Centaurus, is the coldest natural object in the universe found so far. Its temperature is approximately  $-272^{\circ}\text{C}$ , just one degree above absolute zero, or zero kelvin (0 K). Even the temperature of outer space – more correctly, the Cosmic Microwave Background Radiation – is a slightly warmer 2.7 K.

A nebula is a cloud of dust and gas ejected from a bright, central star towards the end of its life, when it has used up its nuclear fuel. The Boomerang Nebula is a so-called pre-planetary nebula, at a very early stage of this process. Its ultracold temperature was discovered by two astronomers in 1995, one of whom – Dr Raghvendra Sahai of NASA's Jet Propulsion Laboratory – had predicted the existence of such cold regions in a paper published five years previously.

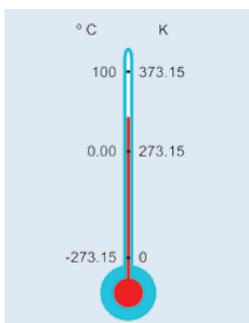
The nebula was given its name a decade before that by two astronomers who observed it in 1980 using the 3.9 m Anglo-Australian Telescope in Australia. Unable to see it clearly, they noted a slight asymmetry in the nebula's lobes, which brought the shape of Australia's iconic boomerang to mind. But more detailed images captured in 1998 and 2005 by the Hubble Space Telescope, launched by the space shuttle *Discovery* in April 1990, revealed that the nebula had a bow-tie shape.



ALMA (ESO/NAOJ/NRAO); NASA/ESA Hubble; NRAO/AUI/NSF

**A composite image of the Boomerang Nebula, showing the hourglass-shaped outflow detected with ALMA observations (orange) on top of an image from the Hubble Space Telescope (blue). The hourglass outflow stretches more than three trillion kilometres from end to end, and is the result of a jet that is being fired by the central star.**

More recently, Sahai and co-workers using the Atacama Large Millimetre/submillimetre Array (ALMA), an international radio astronomy facility in Chile, released images in 2013 and 2017 that showed a much broader central disc and a more elongated outflow. The outflow is expanding



The kelvin was previously defined as the fraction  $1/273.16$  of the thermodynamic temperature of the triple point of water – where the solid, liquid and gaseous phases coexist at thermodynamic equilibrium. In November 2018, the member states of the International Bureau of Weights and Measures voted to redefine the International System of Units (SI), changing the definition of the kelvin as well as the kilogram, ampere and mole. The changes came into force on 20 May 2019, and the kelvin is now defined in terms of the Boltzmann constant ( $k$ ), which has been given the fixed value of  $1.380\,649 \times 10^{-23}$ , expressed in joules per kelvin. The scale remains the same, with one kelvin being the same magnitude as one degree on the Celsius scale. 'Absolute zero' at 0 K is theoretically the lowest possible temperature, with a complete absence of thermal energy.



Roscosmos/NASA

**NASA's Cold Atom Laboratory orbits Earth on the International Space Station.**

at a speed of 590 000 km per hour, and spans a distance of almost four light years across the sky – equivalent to more than three trillion kilometres from end to end, which is about 21 000 times the distance from the Sun to the Earth.

### Coldest place in space

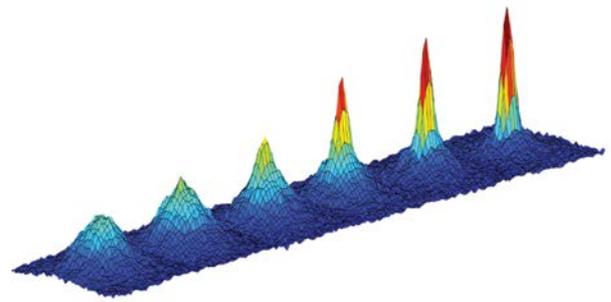
In May 2018, NASA launched its Cold Atom Laboratory to the International Space Station, where it is being used to conduct fundamental physics research. More specifically, the lab can produce Bose-Einstein condensates (BECs) – considered the fifth state of matter after solids, liquids, gases and plasmas – and give researchers more time to study them.

BECs don't form naturally, but can be produced by cooling atoms in a dilute gas to ultralow temperatures, very close to absolute zero. As predicted in the 1920s by Albert Einstein on the basis of concepts formulated by the Indian physicist Satyendra Nath Bose, ultracold atoms move so slowly that they 'condense' into the same quantum state and start to behave like one continuous wave instead of discrete particles. This allows microscopic characteristics to be visible at a macroscopic scale.

On Earth, the BECs are pulled down by gravity and fall quickly to the bottom of any apparatus used to study them, limiting observation times to less than a second. Magnetic fields can be used to 'trap' the atoms and hold them still, but that restricts their natural movement. In the microgravity environment of the space station, BECs can float, which means they can be observed for longer. In its first two years of operation, the Cold Atom Lab has provided thousands of hours of microgravity experiment time to scientists on Earth – since the lab is operated remotely from NASA's Jet Propulsion Laboratory at Caltech – allowing them to repeat their experiments and make adjustments as needed. The ultracold temperatures are reached using a three-step process that involves laser cooling, evaporative cooling and adiabatic expansion. For a simple explanation, search YouTube for the video 'A recipe for cooling atoms to almost absolute zero'.

### Coldest natural place on Earth

The coldest place on Earth is in Antarctica, but it's not at the South Pole. Nor is it at Russia's Vostok Station, which holds the record for the lowest air temperature ( $-89.2^{\circ}\text{C}$ )



NASA/JPL-Caltech

**This graph shows the changing density of a cloud of atoms as it is cooled to lower and lower temperatures (left to right) approaching absolute zero (0 K). The emergence of a sharp peak confirms the formation of a Bose-Einstein condensate – a fifth state of matter – occurring here at 130 nanokelvin (one nanokelvin is one billionth of a degree).**

ever measured by a weather station, on 23 July 1983. Using satellite data, scientists have found that about 100 sites on the high East Antarctic Plateau probably reach minimum air temperatures of  $-94^{\circ}\text{C}$  during July and August, when the sun never rises above the horizon.

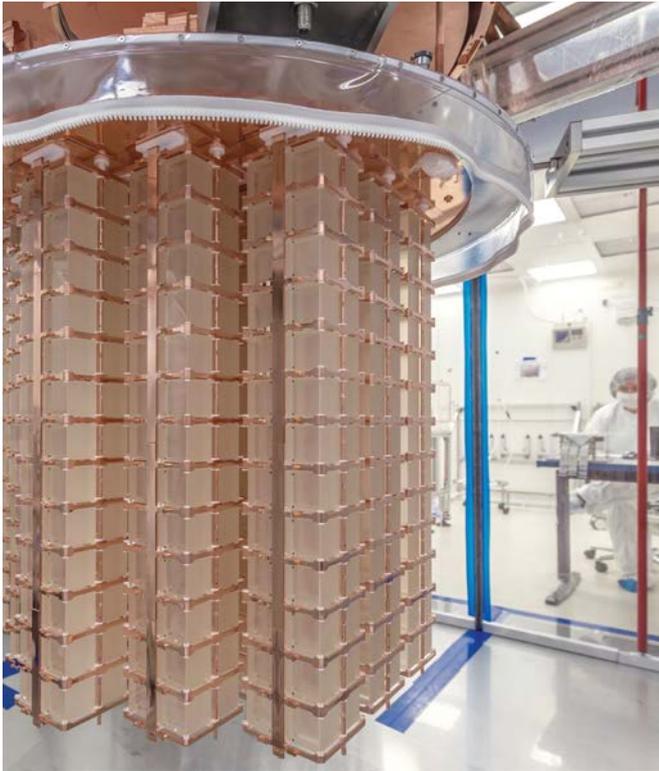
The scientists, led by Dr Ted Scambos of the National Snow and Ice Data Centre in the United States, analysed data for the period 2004 to 2016 collected by the MODIS instrument aboard NASA's Terra and Aqua satellites, as well as instruments on NOAA's Polar Operational Environmental Satellites. These measure the temperature of the snow surface, rather than the air above it, but by comparing the data with that collected by Vostok Station and three automatic weather stations in the vicinity, the scientists inferred that the near-surface (2 m) air temperature is  $4^{\circ}\text{C}$  warmer than the minimum  $-98^{\circ}\text{C}$  snow temperatures.

These lowest temperatures occur in shallow depressions, approximately 2 m deep and less than  $200\text{ km}^2$  in area, at elevations of 3 800 m to 4 050 m. For the temperature to drop to these record levels, skies must be clear and calm, and the air must be extremely dry, because water vapour

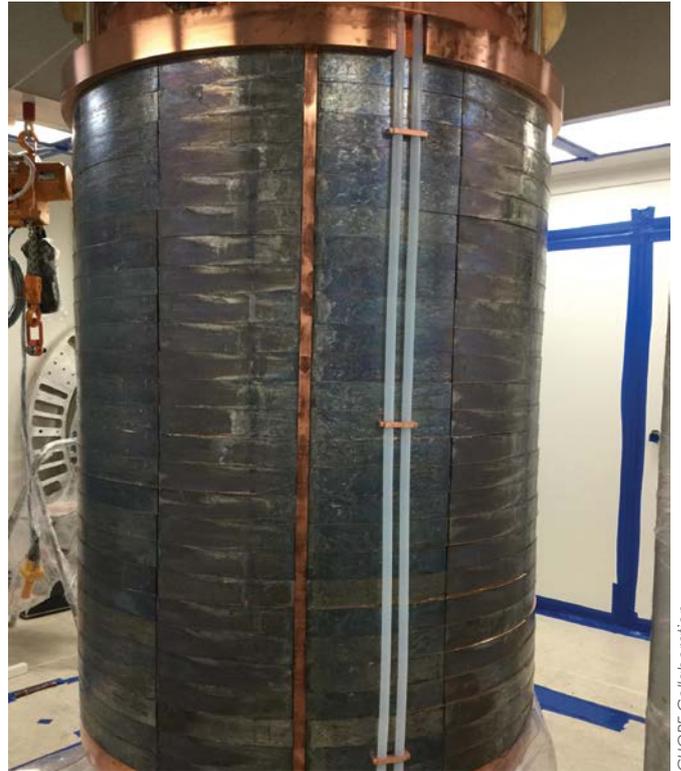


NASA

**Russia's Vostok Station on the East Antarctic Plateau holds the record for the lowest air temperature ever measured by a weather station, but satellite imagery has revealed colder spots in the surroundings.**



**The CUORE detector, made up of 19 copper-framed towers each housing 52 cube-shaped crystals, was assembled in a specially designed clean room to help protect it from contaminants. The outer casing includes a layer of radiation-depleted lead that was recovered from a 2 000-year-old Roman shipwreck.**



CUORE Collaboration

blocks the loss of heat from the snow surface. Cold, dense air descends and pools above the surface, remaining in the depressions for several days. This allows the surface, and the air above it, to cool still further, until the clear, calm and dry conditions break down and the air mixes with warmer air higher in the atmosphere.

### Coldest mountain 'heart'

In an underground laboratory deep beneath a mountain in Italy, an international team of scientists are cooling a chamber the size of a vending machine to a mere 10 millikelvin, or  $-273.14^{\circ}\text{C}$ , to conduct experiments aimed at finding evidence of a rare particle process. The project is called CUORE, which is an acronym for the Cryogenic Underground Observatory for Rare Events, but also means 'heart' in Italian. The process it is designed to confirm is the hypothesised neutrinoless double-beta decay, which would provide insights into how matter was created in the universe.

Double-beta decay, which has already been proven, is a process that occurs in a few naturally occurring radioactive isotopes. It involves two neutrons – the uncharged particles in an atom's nucleus – becoming two protons and emitting two electrons and two antineutrinos. Antineutrinos are the antiparticles, or antimatter counterparts, to neutrinos.

By contrast, neutrinoless double-beta decay would not produce any antineutrinos. This is because they would erase each other in the decay process, proving that the neutrino is its own antiparticle, as the Italian scientist Ettore Majorana hypothesised in 1937. Discovery of this neutrinoless process would mean that a neutrino and an antineutrino, which are both electrically neutral, are essentially the same particle (called a Majorana neutrino).

The underground facility is part of the Italian National Institute for Nuclear Physics (INFN), but the project involves scientists from some 20 institutions in Italy, the United States, France and China. The CUORE detector consists of 988 cube-shaped crystals made of a highly purified, natural form of tellurium dioxide. These are stacked in 19 copper-clad towers, which are suspended within a tank enclosed by five others, like Russian nesting dolls. The detector is shielded from outside particles, such as cosmic rays constantly bombarding the Earth, by the 1 400 m of rock above it, and by thick lead shielding, which includes a radiation-depleted form of lead that was recovered from an ancient Roman shipwreck.

### Coldest mountain peak in Africa

Mount Kilimanjaro in Tanzania is not only Africa's highest mountain, at 5 895 m above sea level, but is also the highest free-standing mountain in the world. It is a stratovolcano, built up from hardened layers of lava, ash and other pyroclastic material, and has three distinct cones. Two are extinct, while the youngest, Kibo, is considered dormant, having last erupted more than 150 000 years ago, although steam and sulphur are still emitted from its crater.

Kilimanjaro is situated only 370 km south of the equator, but air temperatures at the summit remain below freezing. Its snow- and ice-capped dome often appears to hover over the hazy, sunbaked African plains below, but it is this iconic feature that has become a 'poster child' for the effects of climate change.

Fallen snow compresses into thickened ice masses over many years, and those that flow are known as glaciers. Kilimanjaro had an almost continuous glacial ice cap in 1912, but by the 1980s this had been reduced to three



Benh Lieu Song, CC BY-SA 4.0

**Air temperatures at the summit of Mount Kilimanjaro in Tanzania remain below freezing.**

separate bodies of ice – the northern, eastern and southern ice fields. The retreat continued, and by 2011 only 1.76 m<sup>2</sup> of ice cover remained, representing an 85% loss over a hundred years. Today, it is considered highly unlikely that any ice body will remain after 2060.

Scientists from a number of countries are conducting research on this glacial retreat and its cause, using aerial photography, satellite imagery, laser scans, ground-penetrating radar, meteorological measurements and modelling studies. It is generally agreed that the loss of ice is not the result of increased air temperatures, but rather due to a decrease in atmospheric moisture, causing lower humidity. This not only means that there is less precipitation in the form of snowfall, but there is less frequent cloud cover too, exposing the snow and ice to more solar radiation. Some years, however, experience good snowfall, and this appears to be linked to broader patterns of climate variability associated with the El Niño Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD), also known as the Indian Niño or the Indian Ocean Zonal Mode. For example, warmer sea surface temperatures in the western Indian Ocean during the IOD positive phase raise atmospheric moisture levels, causing higher than normal precipitation in East Africa. El Niño and IOD also increase the frequency of tropical cyclones – intense storms that form over warm oceans – and these may cause heavy snowfall on Kilimanjaro as short-term events.

**Coldest country in Africa**

Lesotho is the country with the coldest temperatures overall, although the city of Ifrane in Morocco holds the African record for the lowest temperature ever observed, as recognised by the World Meteorological Organisation. Ifrane

lies at an elevation of 1 665 m in the Middle Atlas mountain range, and a minimum temperature of –23.9°C was recorded at its meteorological station on 11 February 1935. But the whole country of Lesotho lies above 1 400 m – it is in fact the only independent state in the world that lies entirely above 1 000 m – while the highest point is the 3 482 m Thabana Ntlenyana mountain peak. With a mean elevation of 2 161 m, it is easy to comprehend why Lesotho is known as the ‘Kingdom in the Sky’.

In June and July, minimum temperatures fluctuate around 0°C overnight, but rise to an average 15°C during the day. Snowfalls occur periodically, but research led by Professor Stefan Grab at the University of the Witwatersrand indicates that these were much heavier and more frequent during the first half of the 19<sup>th</sup> century. Back then, snow typically



NASA Earth Observatory

**A satellite image from 11 August 2018 showing a blanket of snow over much of Lesotho.**

remained in the Lesotho Highlands from May to September, but nowadays snow only lasts for an average of 10 days following individual snowfalls.

In a paper published in the Water Research Commission's journal, *Water SA*, Prof. Grab and co-authors note that the change in snow occurrence has a number of implications for the rural communities in the Lesotho Highlands. The more abundant snow of the past would have sustained their water supply during the dry season, but they have adapted to the change by building makeshift channels to divert water from springs. Herders also tend to leave sheep and cattle in the highlands all year round now, which depletes grazing resources and accelerates land degradation and soil erosion. And since the herders have become accustomed to light snowfall, they may be unprepared for periodic extreme events involving blizzards and deep snow, threatening their survival.

### Coldest town in South Africa

Sutherland in the Karoo is considered South Africa's coldest town, with an average annual temperature of only 12°C. Winter brings occasional snowfalls and chilly overnight temperatures, dropping to an average minimum of 3°C during July. Less than 3 000 people live in the town, but it welcomes a steady stream of visitors because the South African Astronomical Observatory (SAAO) field station is perched on a hill 18 km away, at an altitude of 1 800 m. The area's relatively clear, cloud-free skies all year round, together with the lack of light pollution and city smog, provide ideal conditions for astronomy.

For this reason, the SAAO's field station was chosen as the location for the Southern African Large Telescope (SALT) – the largest single optical telescope in the southern hemisphere. It has an 11 m-wide primary mirror, made up of 91 individual 1 m hexagonal mirrors, and can detect light from objects a billion times too faint to be seen with the unaided eye. Construction was completed at the end of 2005, and scientific observations began in 2011, following a period of commissioning and performance verification. SALT is funded by a consortium of international partners from South Africa, the United States, Germany, Poland, India, the United Kingdom and New Zealand.

Apart from SALT, the site has three other optical telescopes owned and operated by SAAO – the 1.0 m and 1.9 m



Sue Matthews

**The South African Large Telescope (SALT) building overlooks a winter wonderland at the SAAO field station near Sutherland.**



Gregor Leigh

**Postdoctoral researchers helped to set up the cryogen-free  $^3\text{He}$ - $^4\text{He}$  dilution fridge in the UCT Physics Department.**

telescopes, as well as the newer 1.0 m Lesedi telescope, installed in 2017. In addition, there are a number of telescopes and instruments that belong to other research organisations, both local and international. A 3D interactive tour of the SAAO field station can be viewed at <https://www.sao.ac.za/sao-vr-tour/tour.html>.

### Coldest facility in Africa

The Physics Department at the University of Cape Town claims the title of the 'coldest place in Africa' because it houses a cryogen-free  $^3\text{He}$ - $^4\text{He}$  dilution fridge that can be used to cool specimens to 10 millikelvin (mK), or  $-273.14^\circ\text{C}$ . The fridge was purchased in 2014 at a 'cool' R6.5 million for the nanoelectronics research group to study material systems and electron transport, but it required repairs after arriving from the manufacturers in Holland in a damaged state, followed by operational refinement and the redesign of some components.

The refrigeration process in  $^3\text{He}$ - $^4\text{He}$  dilution fridges – used for the CUORE project too – relies on differences in thermodynamic characteristics of two isotopes of helium. A liquid mixture of these isotopes will separate into two phases when cooled below the tri-critical point of 867 mK. The lighter  $^3\text{He}$ -rich phase, known as the 'concentrated phase', floats on top of the heavier  $^4\text{He}$ -rich phase, which still contains up to 6.6%  $^3\text{He}$ , so it is known as the 'dilute phase'. By pumping away  $^3\text{He}$  from the dilute phase, more  $^3\text{He}$  will be drawn down by osmotic pressure from the concentrated phase into the dilute phase to maintain the equilibrium concentration of 6.6%. The process of  $^3\text{He}$  crossing the boundary between the two phases is endothermic, absorbing thermal energy, which has the effect of reducing the temperature of the mixture. The process can be likened to blowing on a cup of hot soup to cool it down – by blowing away the steam, more soup can evaporate, cooling what remains in the cup.

The 'cryogen-free' versions of such dilution fridges, also called 'dry' dilution fridges, do not require liquid helium for the initial cooling step. Instead, a mechanical cryocooler is used, and the refrigeration system is a closed-cycle design that continuously recirculates  $^3\text{He}$ . This is beneficial because  $^3\text{He}$  is extremely expensive and subject to periodic shortages in supply.

# Journey to the sea ice



*Honours student Sejal Pramlall shares her experience of participating in a research cruise to the Southern Ocean*

My first step on the Antarctic sea ice felt like landing on the moon. A four-person 'basket' acted as the slow rocket that hoisted me from the comfort of the *SA Agulhas II* into a cold and somewhat desolate world. I stepped onto the ice, and noticed an immense silence, the only sound being the crunch of the snow under the weight of my oversized pumpkin boots. The warm polar attire bore close resemblance to a space suit, both limiting mobility but nevertheless being highly necessary.

The seemingly limitless expanse of the ice attested to the fact that I had now entered an environment that was untouched and uninhabited by man. Apart from my shipmates, human life was thousands of kilometres away, with the nearest other life forms being wild and pristine. I took a breath; the air was crisp and clean. In that instant, I realised that my past aspirations as an oceanographer were materialising at that very moment. My participation in the SCALE spring cruise 2019 had begun in earnest.

I was recruited to the SCALE research expedition as a member of the sea ice team, made up of a combination of University of Cape Town oceanographers and engineers under the supervision of Associate Professors Marcello Vichi and Sebastian Skatulla. Our goal was to perform ice-coring operations and to collect snow and water samples from the various Marginal Ice Zone (MIZ) stations. Each station began



**The sea ice team in transit on the 'basket'.**

with the implementation of thorough safety procedures to ensure the ice could bear the weight of the team.

The collection of samples was conducted efficiently and in accordance with sound scientific procedures. We treated each station as an opportunity to improve, surpassing the previous day's achievements at each chance we had to get onto the ice. When not on the ice, I would be on the bridge conducting ice observations, which consisted of a thorough observation of sea ice conditions every 10 minutes, rolling over every 24 hours. These *in situ* observations provide valuable information that can be used for the validation of satellite data.

Not only did I accumulate invaluable skills in the realm of sea ice data collection, but I was also exposed to numerous scientific fields during my voyage. I was fortunate enough to witness the tagging of two Ross seals, which is an exceptionally rare sighting. Down in the environmental hanger where the UCT biogeochemists dwelled, the CTD (an instrument measuring conductivity, temperature and depth) and Bongo nets were deployed. The CTD recorded data from the various ocean depths, allowing the different water masses that make up our inhomogeneous ocean to be discerned, along with the inherent chemical and biological signals within them. Through the microscope the contents of the Bongo nets were revealed – colourful krill and alien-like critters were the catch of the day, proving that an area that appeared barren to the untrained human eye was bursting with life and productivity.



Sejal Pramall (right) extracts an ice core with another member of the sea ice team.

## Southern Ocean seasonal Experiment (SCALE)

SCALE is a novel interdisciplinary experiment in the south-east Atlantic sector of the Southern Ocean. It aims to advance understanding of the climate sensitivity of the Southern Ocean through improved knowledge of seasonal cycle dynamics in the upper 1 000 m of the water column, and to observe decadal changes in ocean storage of carbon, geotracers and heat.

Research is conducted under five scientific themes:

- Air-sea-ice fluxes
- Biological carbon pump
- Physics to top predators
- Decadal changes in ocean interior
- Digital technology solutions for polar engineering.

Sea ice dynamics are an integral part of each of these themes. The exchange of gases, aerosols, heat and momentum between the atmosphere and ocean through the sea ice is a key factor influencing long-term climate variability and trends. These fluxes are critical to understanding the links between carbon and climate, aerosols and albedo, and the influence of terrestrial particles on ocean biogeochemistry.

Changes in distribution of sea ice are also likely to affect the composition, abundance and productivity of phytoplankton, which could alter the efficiency of the biological carbon pump. In addition, the marginal ice zone

environment is an essential habitat for top predators such as seals and toothed whales throughout the year, and its seasonal variability influences their feeding behaviour.

Sea ice freezing and melting may play an important role in driving the Meridional Overturning Circulation that brings deep waters to the surface in the Southern Ocean. This large-scale circulation is the primary mechanism for the transport and storage of heat, carbon, salt, freshwater and nutrients between ocean basins. Lastly, the polar engineering theme seeks to optimise the engineering of ice-going vessels.

The SCALE spring cruise, which departed from the Port of Cape Town on 12 October 2019 and arrived back on 19 November, was preceded by a three-week winter cruise in July 2019.

[www.scale.org.za](http://www.scale.org.za)



Nine sea ice pancakes were lifted from the ocean during the cruise, so that cores and water samples could be collected.



After removal of the cores, water samples are collected from the holes for further analyses, such as nutrient, chlorophyll *a* and salinity measurements.

SCALE has proven to be the umbrella under which numerous disciplines can thrive, as shown by the extensive cooperation between researchers from different fields. Witnessing the teams working together with the common goal of furthering our understanding of the Southern Ocean was truly inspiring. The success of the SCALE cruise confirms my belief that a multidisciplinary approach is the key to progress. This is how all science should be conducted, by exuding benevolent support and inclusivity for researchers from various backgrounds.

I am grateful to have been involved in such an expedition, where I was part of a team that became family, I learnt lessons that could only be gained through experience, and

made memories that will last a lifetime. This experience reminds me of an African proverb I have heard: "If you want to go fast, go alone; if you want to go far, go together."

*Sejal Pramlall*  graduated from UCT with a BSc honours degree in Ocean & Atmosphere Science, and was awarded the class medal for being the top achiever in her academic year. She is now registered for an MSc degree with the Spectral Remote Sensing Laboratory at the University of Victoria, Canada.

*This article was originally published in the December 2019 issue of Science Matters, the newsletter of UCT's Science Faculty. <http://www.science.uct.ac.za/newsletters-1>*



Sejal Pramlall (left) with fellow UCT student Kelsey Kaplan.

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Chemical systems: The hydrosphere

### PHYSICAL SCIENCES: GRADE 11

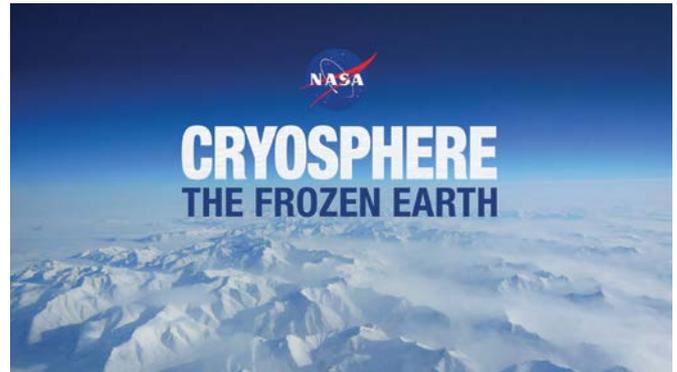
Matter and materials: Chemistry of water

# Monitoring ice from space

The Antarctic and Greenland ice sheets are losing ice six times faster than in the 1990s, having caused a rise in sea level of at least 17.8 mm in the intervening period. This was reported in March 2020 by the team who conducted the Ice Sheet Mass Balance Intercomparison Exercise (IMBIE), involving 89 polar scientists from 50 international organisations. The IMBIE team used data from 11 different satellite missions, including measurements of the ice sheets' changing volume, flow and gravity.

The findings, published in two separate papers in *Nature*, show that Greenland and Antarctica lost 6.4 trillion tonnes of ice between 1992 and 2017. Some 60% of the resulting sea level rise was due to ice losses in Greenland and 40% to Antarctica. Almost all of the ice lost from Antarctica, and half of that lost from Greenland, has been triggered by oceans melting their outlet glaciers. The remainder of Greenland's ice losses are due to rising air temperature, which has melted the ice sheet at its surface.

The study was supported by the European Space Agency's (ESA) Climate Change Initiative and the National Aeronautics and Space Administration's (NASA) Cryosphere Programme.



**The cryosphere is the collective term used for all the frozen parts of our planet, including ice sheets, glaciers, sea ice, lake and river ice, snow cover, permafrost and seasonally frozen ground.**

*Sea ice is frozen ocean water, whereas an ice sheet is a mass of glacial land ice larger than 50 000 km<sup>2</sup>.*

## Satellites in sync

NASA's ICESat and ESA's CryoSat-2 were among the 11 satellite missions used for the IMBIE study. While many other satellites can measure changes in the spatial extent of ice, these two measure ice height, which can be used to work out changes in thickness and volume of ice. They do this in different ways though – ICESat uses laser altimetry, while CryoSat-2 uses radar altimetry.

The original ICESat (an acronym for Ice, Cloud and land Elevation Satellite) provided data from 2003 to 2009, before being decommissioned in 2010. ICESat-2 was launched in September 2018, and has a better instrument, called the Advanced Topographic Laser Altimeter System, or ATLAS. Like the previous altimeter, it times how long it takes photons in pulses of light sent down to Earth to return to the satellite in order to measure surface elevation, but the ATLAS laser is split into six beams and has an extremely high pulse rate of 10 000 pulses per second. This means that ATLAS can take measurements every 0.7 m along the satellite's ground path and with such precision that scientists can determine the year-to-year change in ice thickness to within a couple of centimetres.

CryoSat-2 was launched in April 2010, five years after the first one was destroyed during its launch in Russia because of a rocket malfunction. The satellite's primary payload is the

Synthetic Aperture Radar (SAR) Interferometric Radar Altimeter – called SIRAL. It works by sending radar pulses towards the Earth's surface and studying the returning echoes.

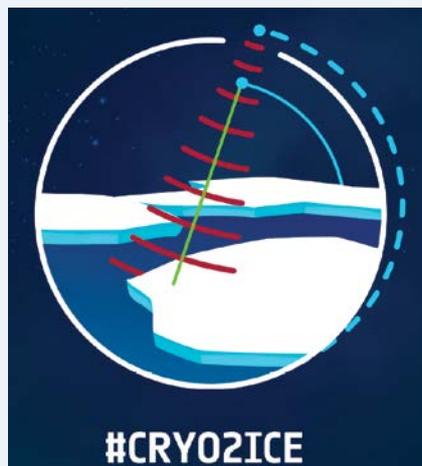
In the last two weeks of July 2020, ESA performed a series of thruster burns to change the orbit of CryoSat-2 so that it overlaps with that of ICESat-2 every 30 hours or so for a 3 000 km stretch over the Arctic Ocean, allowing for almost simultaneous measurements of sea ice.

This is particularly useful because the laser light from ICESat-2 reflects off the surface of the snow layer on top of the sea ice, whereas the radar waves from CryoSat-2 penetrate the snow and are reflected off the sea ice itself. Sea ice thickness is typically estimated by first measuring how much of the floating ice protrudes above sea level,

but overlying snow can weigh the ice down, so that the ice sits lower in the water. Having both measurements will allow scientists to measure the snow layer thickness and produce substantially improved estimates of sea ice thickness.

In the future, it's possible that the orbit will be realigned again, so that the overlap is over the Antarctic.

**The CRYO2ICE campaign aligned the orbits of ESA's CryoSat-2 and NASA's ICESat-2 satellites.**





# Microscopic life on the frozen continent

*Don Cowan tells us about the terrestrial microbes of Antarctica, and an exciting new research programme*

The McMurdo Dry Valleys of Antarctica represent one of the most extreme environments on Earth. Temperatures might rise a little above 0°C for a few months during the summer 24-hour daylight period, but water is always scarce. In winter, when the sun never rises for three months, soil temperatures can plummet to -60°C. It is perhaps surprising that anything can survive these conditions, but research by our team at the University of Pretoria's Centre



**Prof. Cowan collecting samples in the Antarctic Dry Valleys area.**

for Microbial Ecology and Genomics has shown that a wide diversity of soil microorganisms thrives here.

The most active and complex terrestrial soil microbial communities exist in protected niche habitats, either inside or underneath transparent rocks. These endo- (inside) and hypo- (underneath) lithic communities are biodiversity and functional 'hotspots' in otherwise low-biomass environments. They are dominated by photosynthetic cyanobacteria (also known as blue-green algae), which provide carbon, nitrogen and energy to non-photosynthetic, or heterotrophic, members of the microbial community. Heterotrophs in the lithic communities include many species of bacteria, fungi and even algae and archaea.

These communities only exist because the overlying quartz rock allows enough light to pass through to support cyanobacterial photosynthesis, while protecting the entire microbial community from destructive environmental conditions, particularly extreme desiccation and harmful UV radiation. Interestingly, there is no temperature advantage in these lithic habitats; the organisms have evolved to metabolise at low temperatures and to survive the effects of freezing.

Two very interesting and very different mechanisms have evolved for the protection of cells from freeze damage: special ice-nucleation proteins in the cytoplasm trigger the rapid crystallisation of water into very small ice crystals that do not puncture cell membranes, and biosynthesis pathways redirect stored carbon in the cell to synthesise and accumulate compatible solutes (sugars and sugar alcohols), which depress the freezing point of water in the cytoplasm.

Over two decades, my Antarctic terrestrial studies have focused on many aspects of the microbiology, ecology, function and adaptation of microorganisms in Antarctic soils, but they essentially aim to answer the following key questions:

- what is there (diversity)?
- what is it doing (functionality)?
- how does it survive (adaptation)?
- how does it respond to change (resilience and evolution)?

These studies are principally funded by the National Research Foundation through the South African National Antarctic Programme (SANAP). The most recent three-year tranche of funding, which started in 2017, supported research that represented another step forward in our ongoing investigations of extreme microbiology. The focus was on adaptation and community structural and functional resilience, the latter being at the forefront of the minds of the world's ecologists, since climate change patterns have already resulted in significant warming trends across much of coastal and maritime Antarctica. The way in which sensitive, specialised and unique Antarctic biological communities may respond to climatic changes is currently unknown, and is cause for concern amongst the Antarctic conservation community.

Environmental samples collected from the Antarctic Dry Valleys during a 2018 field expedition are being used in a series of experiments, based on next-generation sequencing technologies that allow for rapid sequencing of the nucleic acids, DNA and RNA. The study of a collection of genetic material from a mixed community of organisms, as found in our environmental samples, is termed metagenomics, and it enables us to investigate genome evolution, functional capacity and metabolic resilience in Antarctic soil microbial communities.

My involvement as an international collaborator in a new Australian-led research programme also brings exciting opportunities for the Centre for Microbial Ecology and Genomics team. In April 2020 the Australian government awarded Aus\$36 million to Monash University for the programme, called 'Securing Antarctica's Environmental Future' (SAEF), which will include participants from some 30 organisations in Australia and abroad. The programme leader, ex-South African Professor Steven Chown, is a world-renowned ecologist and is the current President of the Scientific Committee on Antarctic Research – the leading international body facilitating research in, from and about Antarctica.

The focus of the SAEF programme is on the future conservation of Antarctica, which is experiencing rapid

climate change, with warming marine waters and melting terrestrial glaciers. The implications of climate change go far beyond the continent itself, with potentially serious global impacts such as a rise in sea levels and changes in ocean productivity. The programme objectives include surveys of species diversity – from microorganisms to higher eukaryotes – across the Antarctic continental and sub-Antarctic zones, to investigate their biogeographical distributions, and to assemble the data to inform future regional conservation strategies. One of the core outcomes of the programme is the development of effective environmental stewardship strategies to secure Antarctica into the future as a natural reserve.



**Hypolithic cyanobacteria-dominated microbial communities, like this one on the underside of a quartz pebble, are often referred to as the 'tropical rainforests of the Antarctic deserts'.**



**A green layer inside a rock is evidence of an endolithic microbial community supported by photosynthetic cyanobacteria.**

In parallel, the SAEF programme will study trends in human activity in the Antarctic regions, particularly the growing tourism industry, as a major factor in future regional conservation strategies and policies. Tourism brings hundreds of thousands of visitors to the continent annually, and although well controlled at present, uncontrolled tourism has the potential to directly or indirectly damage sensitive Antarctic biological communities – for example, by physical disturbance, contamination, or the introduction of non-indigenous species that may outcompete the local species. Managing Antarctic tourism, for the benefit of both the tourists and the continent, is therefore an important future strategic objective.

*Prof. Don Cowan  is the director of the Genomics Research Institute and the Centre for Microbial Ecology and Genomics at the University of Pretoria. He is an NRF A1-rated researcher and has been a Member of the Academy of Sciences of South Africa (ASSAf) since 2007.*



**The desert sands of the Victoria Valley in East Antarctica.**

BLOOD 1.3.13

BLOOD 1.4.13

BLOOD 1.3.17

BLOOD 1.4.17

# Frozen in time

## a biological back-up of species

*Kim Labuschagne explains how the SANBI wildlife biobank supports biodiversity research and conservation*

A biobank is a large collection of biological samples and associated data, amassed for research and conservation purposes. These collections of samples can be from plants, animals, microorganisms or humans, but whatever material is stored, it needs to be kept at an optimal temperature to ensure its viability for further use.

The wildlife biobank at the South African National Biodiversity Institute (SANBI) has been dedicated to the long-term collection, curation and archiving of biodiversity samples for more than 20 years. Its samples include those from species assessed according to the IUCN Red List categories as extinct in the wild, critically endangered, endangered and vulnerable. The samples are collected from wild (*in situ*) and captive (*ex situ*) animals – both alive and dead – and may be blood, skin or tissue, hair and feathers, nails, scales, organs, bones, hooves, sperm or other materials.

A wide range of current and retrospective (or backward-looking) studies can be done using these collections. For example, if a disease ravages an animal population, researchers would be able to compare samples with those collected years ago to understand the progression of the disease, its impact on certain tissues, or any genetic changes that increased susceptibility.

The SANBI wildlife biobank serves as a science platform to both the national and international research and conservation community. It is able to support a variety of disciplines, including forensic sciences, comparative

nutrition, epidemiological surveys, reproductive technologies, genetics and pathology diagnoses.

Currently, the biobank collection consists of more than 180 000 different samples from approximately 70 000 individual animals. Over 880 species from 204 families are represented, and the samples were collected from 24 countries. These samples are stored at a range of different temperatures – from room temperature (approximately 21°C) and normal fridge (4°C) and freezer (–20°C) temperatures, to ultralow (–80 °C) and cryogenic (–150°C to –196°C) temperatures.

The majority of the collection consists of blood samples, and these are stored in –80°C freezers in 1.8 ml tubes. Such low temperatures ensure that the sample is not exposed to freeze–thaw cycles that often occur in warmer freezers. Blood is one of the most important samples to store from an animal as it is able to answer a variety of questions. For example, has it been exposed to any poisons or toxins in the environment? What does the blood indicate about the animal's health? What species is it, and where is the individual from? These last two questions can be answered by extracting DNA from a tiny sample of blood and using it to complete a DNA profile that is unique for each individual. This genetic information could even help investigators determine whether confiscated animals or animal products were legitimately traded or illegally trafficked.

More than 20 000 samples in the collection are stored either in mechanical freezers at –50°C, or in tanks holding



**Sperm samples stored in liquid nitrogen tanks.**

liquid nitrogen at a very chilly  $-196^{\circ}\text{C}$  (just below the boiling point of liquid nitrogen). We refer to this method of storage as cryopreservation. Along with a dose of biological antifreeze, this ensures that the cells remain in a somewhat live state. They become biologically inert, and can be preserved for years if kept at temperatures below  $-130^{\circ}\text{C}$ . The tanks are maintained by adding liquid nitrogen on a weekly basis to ensure that the samples remain submerged. This topping up is necessary to counteract the liquid nitrogen lost through 'boil off' as heat leaks into the tank, although even the vapour inside the tanks can remain below  $-130^{\circ}\text{C}$ .

The cryopreserved samples include sperm samples collected from pre-2000 to the current day, as well as an irreplaceable fibroblast (or cell culture) collection that dates back to the early 1980s. This includes important species such as the now extinct western black rhinoceros (*Diceros bicornis longipes*) and the critically endangered northern white rhinoceros (*Ceratotherium simum cottoni*) – of which

only two surviving animals remain in the world, both females – as well as whale and dolphin species, various cat species, and even a hybrid between a black and white rhinoceros.

In 2010 the SANBI wildlife biobank was part of an international collaboration called Operation Frozen Dumbo. Sperm samples were collected from wild African elephants (*Loxodonta africana*) and stored in liquid nitrogen tanks at the biobank. Once all the health and export permits were obtained, these tanks were sent to France and the sperm samples were used to artificially inseminate a female elephant at one of the European zoos. The procedure was successful, and 22 months later a calf was born.

A cell culture is grown from a biopsy of skin or tissue, which is chopped into chunks the size of a pinhead and then placed in a petri dish with a nutritious media. The petri dish is left in an incubator set at the same body temperature of the animal it was collected from. The cells begin to divide (mitosis) and eventually cover the entire petri dish. When the cells' growth starts to slow down, it is time to freeze them. And this is where the antifreeze comes in – it is added to make sure that freezing them at such low temperatures won't kill them, but rather just inactivate them, so that they are 'frozen in time'.

As technologies advance, more uses for these cryopreserved samples are being discovered, the most recent being stem cell research. Stem cells are cells that can develop into many different cell types in the body. Scientists have even been able to reprogramme skin-derived stem cells into heart cells that beat in the petri dish.

Samples stored in biobanks around the world will continue to be used in ever more advanced ways to conserve our precious biodiversity, and in some cases, to rescue species on the brink of extinction.

Kim Labuschagne  is the Biobank Curator at the South African National Biodiversity Institute (SANBI), housed at the National Zoological Gardens in Pretoria.



**A lion biopsy is broken up into tiny chunks to be incubated in petri dishes filled with nutritious media. The resulting cell culture is then frozen in liquid nitrogen.**

# Freezing for pollution prevention

As the need to protect the planet – and the life-support systems on which we depend – is recognised worldwide, tighter restrictions are being imposed on the quantity and quality of effluents and emissions generated by industry. The race is on to find sustainable and cost-effective ways of removing contaminants from these waste discharges. Here, *Quest* reviews some innovative technologies that use freezing for this purpose.

## Eutectic freeze crystallisation

Industries producing highly contaminated effluent are required to treat these effluents to a set standard before either releasing them into the environment, sending them to a municipal wastewater treatment works, or reusing them in some way. This typically involves a number of membrane filtration steps, often culminating in reverse osmosis to separate out the dissolved salts, metal ions and other minute particles. In the process, these contaminants are concentrated into a highly saline brine, which presents a disposal problem. Usually brines are discharged into evaporation ponds, but these take up a lot of space and risk contaminating groundwater if the lining fails.

In 2007, researchers in the chemical engineering department at the University of Cape Town began investigating a novel technology to deal with these brines, while also recovering the salts for other purposes. The technology, called eutectic freeze crystallisation (EFC), involves cooling down the brine to its eutectic point – the lowest temperature at which it can exist in the liquid phase. Beyond that, the water in the brine crystallises out as ice, which floats on the surface, and the contaminants crystallise out as salts, which sink to the bottom.

Individual salts can be recovered, because each has its own unique temperature at which it will crystallise out in a particular mixture. During one laboratory experiment using brine from a coal mine, for example, the research team recovered calcium sulphate – more commonly known as gypsum – as well as sodium sulphate. Apart from being the material from which ceiling boards, drywall and plaster are made, gypsum is also used as a fertiliser in agriculture and as a filler in dentistry and orthopaedic surgery. Sodium sulphate is a key ingredient of soaps and detergents, but it is used in the production of paper, glass, textiles and a variety of other materials too.

Prof. Alison Lewis, who leads the team in the department's Crystallisation and Precipitation Research Unit, explains that work on EFC started overseas in the 1950s. Although it was



The eutectic freeze crystallisation (EFC) unit designed and built by Prentec at the Tweefontein Colliery in Mpumalanga, based on research done at UCT's chemical engineering department. Much of the research was funded by the Water Research Commission.

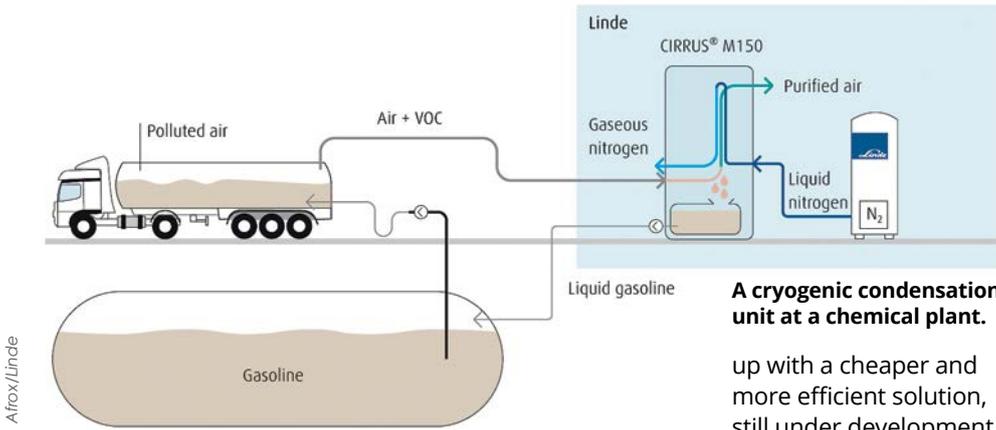


Prof. Alison Lewis (far left) and postgraduate students at the commissioning of the EFC pilot plant at Eskom's Research and Innovation Centre in April 2016.

found to be technically feasible, freezing was too expensive then to make it financially viable. Modern-day compressors have improved the outlook, but capital costs still make it prohibitively expensive. Nevertheless, Eskom commissioned a pilot plant at its Research and Innovation Centre at Rosherville in April 2016, and investigations are continuing. A larger system was also installed in 2017 at Glencore's Tweefontein Colliery, but the feed stream was found to be too dilute for effective use of EFC. It is anticipated that research will resume once the process has been modified to concentrate the brine.

## Cryogenic condensation

Many industrial processes also emit volatile organic compounds (VOCs), which are organic compounds – containing carbon – that readily produce vapours at room temperature. These are released as gases into the air, where they may react in sunlight with nitrogen oxides to form ground-level ozone and photochemical smog. Common products such as paints, inks, varnishes, glues and solvents release VOCs, some of which are toxic and carcinogenic. The manufacturing of these and other



Afrox/Linde

**When fuel tankers are filled, air is naturally forced out. In some countries, fuel depots are obliged by emission regulations to prevent these fumes from escaping into the environment. Cryogenic condensation units can treat the fumes by condensing out the volatile organic compounds. These recovered VOCs can then be recycled.**

chemicals for both home and industrial use accounts for some of the emissions of VOCs, but any burning of fuel – including petrol, diesel, coal, natural gas and wood – releases VOCs. This means that power plants, refineries, smelters, factories, vehicles and even veld fires all contribute to atmospheric levels of VOCs.

Since VOCs pose a threat to human health and the environment, air quality legislation typically includes standards for VOC emissions with which facilities must comply. Cryogenic condensation is a cost-effective way of reducing VOC emissions. By cooling the exhaust gas stream with liquid nitrogen, and hence lowering the vapour pressure, the volatile components condense and then freeze.

Depending on the composition of the exhaust stream and the selected temperature, which can be adjusted by controlling the flow rate of the liquid nitrogen inside the cryogenic condensation unit, VOCs can be recovered as either liquids or solids. These can then be stored for safe disposal, reuse or sale. Recovery performance is typically better than 99%, so even stringent emission standards can be met. The liquid nitrogen used for cooling does not come into contact with the exhaust stream, so it does not become contaminated. In the process it is fully vaporised into nitrogen gas, and can either be released into the air (remember that 78% of air is made up of nitrogen) or captured for reuse in other processes within the facility.

Cryogenic condensation systems can cope with fluctuating flow rates and VOC concentrations in mixed exhaust streams, and they do not produce any harmful by-products because the process relies simply on phase change. Modular systems of different sizes are available, so cryogenic condensation is even used for controlling VOC emissions from tanker trucks and ships.

### Cryogenic carbon capture

Coal-fired power plants are a major source of emissions of carbon dioxide (CO<sub>2</sub>), the primary greenhouse gas contributing to global warming. Various technologies exist to reduce these emissions, but a chemical engineering professor at Brigham Young University in Utah, USA, came



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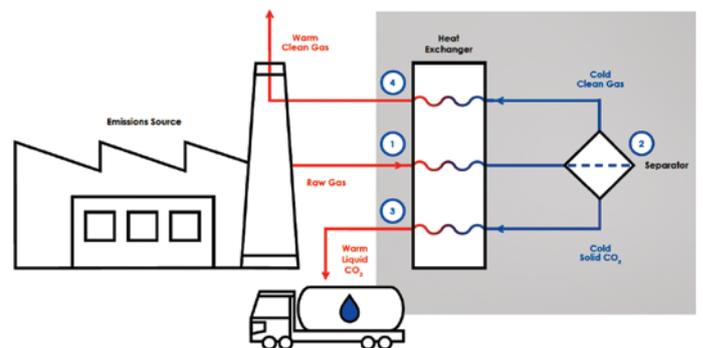
### A cryogenic condensation unit at a chemical plant.

up with a cheaper and more efficient solution, still under development, called cryogenic carbon capture (CCC).

Prof. Larry Baxter's CCC technology freezes the CO<sub>2</sub> out of the exhaust gas as dry ice – the solid form of CO<sub>2</sub>. By cooling the CO<sub>2</sub> to approximately -140°C, the gas transforms into the solid without passing through the liquid phase, which is known as desublimation. The dry ice is then separated from the non-condensable gases, typically nitrogen. Both the dry ice and the cold nitrogen are used in recuperative heat exchangers to assist in cooling down the incoming waste stream. During the recuperative step, the dry ice melts, forming liquid CO<sub>2</sub> that is delivered at ambient temperature. This so-called 'captured' CO<sub>2</sub> can be used in many applications, including biofuels production.

The CCC technology has the potential to reduce carbon emissions from coal-fired power plants by 95–99% at half the cost and energy of alternative carbon capture technologies. In addition, the process removes other pollutants such as sulphur oxides, nitrogen oxides and mercury. The remaining gas is nearly pure nitrogen, and can be safely released to the atmosphere.

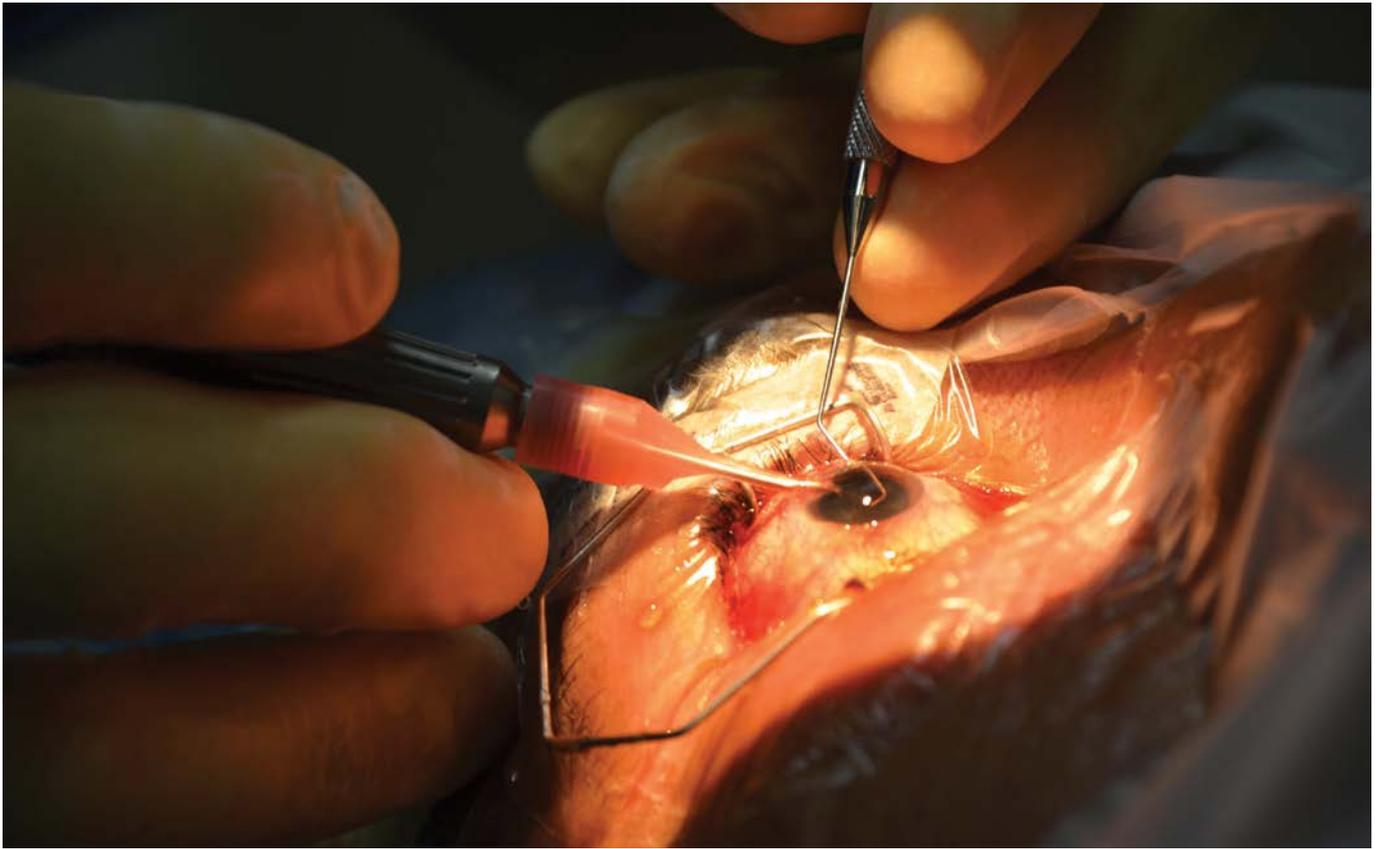
Prof. Baxter co-founded a start-up with his son to commercialise the CCC technology. Sustainable Energy Solutions has to date been funded mainly by government grants, as the technology would help the USA reach its targets for emissions reduction. Promising results were achieved in tests conducted at a power plant during 2019, and the intention is to scale up to a pilot plant soon.



Sustainable Energy Solutions

**The CCC process (1) cools a dirty exhaust gas stream to the point that the CO<sub>2</sub> freezes, using mostly heat recuperation, (2) separates solid CO<sub>2</sub> as it freezes from the clean gas, (3) melts the CO<sub>2</sub> through heat recuperation and pressurises it to form a pure liquid, and (4) warms up the clean, harmless gas before releasing it to the atmosphere.**

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# OUR INNOVATION NATION

*Mike Bruton tells us about some local inventions that put South Africa on the world stage*

Did you know that a South African ophthalmologist used his own invention to operate on Nelson Mandela’s eye the day before his inauguration as President? Or that one of our greatest inventors was also a war hero?

## **Cryoprobe**

Dr Selig Percy Amoils briefly studied mechanical engineering prior to attending medical school at the University of the Witwatersrand, where he qualified in 1956. He used his combined training in engineering and medicine to good effect when he invented the ‘cryoprobe’, a pencil-shaped device with a frozen tip that is used for eye surgery. When he first demonstrated the device at the University of Oxford in 1965, he was still a young, unknown medical doctor, but his invention made him famous as it changed the course of cataract and retinal surgery worldwide.

The cryoprobe works by freezing gas that is released from a small nozzle under high pressure in a closed tube. When the probe is inserted into a cut in the eye and the gas is switched on, it freezes to a cataract, which can then be removed. In 1983 Dr Amoils used the cryoprobe to cure British Prime Minister Margaret Thatcher of retinal detachment after laser surgery had failed to do so. Then, in May 1994, he famously removed a cataract from President Mandela’s left eye the day before his inauguration.

Miraculously, Madiba was able to read his speech at the ceremony without using spectacles!

Dr Amoils also invented the rotary epithelial scrubber, an improvement on the brush first developed by the Greek ophthalmologist Ioannis Pallikaris to remove epithelial cells from the cornea in preparation for laser eye surgery. Then, in 1970, he developed diamond vitrectomy cutters, a group of medical instruments that facilitate very fine control of blade depth during eye surgery, as well as the oval comparator to control astigmatism after cataract surgery.

Dr Amoils was richly rewarded for his multiple contributions to ophthalmology. In 1975 he received the Queen’s Award for Technological Innovation and the Medal of Honor from the US Academy of Applied Science.



**The South African Mint’s latest range of collectable coins includes the 2020 Crown and Tickey series in sterling silver honouring Dr Amoils’ invention.**

South African Mint

In 2005, then President Thabo Mbeki awarded him the Silver Order of Mapungubwe for 'Excellence in the field of ophthalmology and for inspiring his colleagues in the field of science'.

### Tellurometer

Trevor Wadley was arguably our greatest inventor, our own Thomas Edison. He was born in Durban, the seventh child in a family of 10, and from an early age was an avid tinkerer, taking things apart to see how they worked. He once connected the family telephone to a radio speaker so that he could listen to his sister's calls to her boyfriend! Later in life he re-engineered an electric lawnmower into a small electric car. After obtaining electrical engineering degrees from the universities of Natal and the Witwatersrand, he served in the Signal Corps during the Second World War, during which he made such important contributions to the design of radio and radar equipment that he was promoted from lieutenant to major in just four years.

Wadley's radio innovations ensured, in particular, that platoons on the battlefield could stay in contact with their commanders at headquarters. During the war he also developed the 'panoramic adapter' that allowed the viewer to monitor a wide range of radio frequencies in a particular waveband, which was of great strategic value.

After the war Wadley joined the telecommunications research laboratory of the newly formed CSIR, where he perfected the Wadley loop receiver, a unique circuit for cancelling frequency drift. In 1947 he invented the automatic ionosonde, which measures radio wave reflections from the ionosphere. The reflectivity of the ionosphere is what makes the use of shortwave radio for long-distance communication possible, so it was very useful to be able to study, understand and predict its behaviour.

In the same year, he developed one of the first practical broadband radios, known as the Barlow-Wadley broadband radio. This was followed in 1948 by the first crystal-controlled radio, the all-wave communications receiver, which became the standard high-frequency radio used by the British Navy, and was made by RACAL in England. Wadley also developed the Wadley transistorised receiver and the rack-mounted receiver, which was used by the BBC for its international broadcasts.

But Wadley's greatest invention, made in 1954, was the tellurometer or 'earth measurer', a revolutionary device that used radio waves to measure distances accurately. The tellurometer measured the travel time of a radio wave between two parabolic reflectors to an accuracy of three parts per million over a range of 3–50 km, and revolutionised land surveying worldwide. By 1958 tellurometers were in use in more than 60 countries and their export earned South Africa over R300 million (in 1950s terms) in foreign earnings.

Wadley received many international awards, including an honorary doctorate from the University of Cape Town in 1976, and in 1979 a postage stamp was issued to

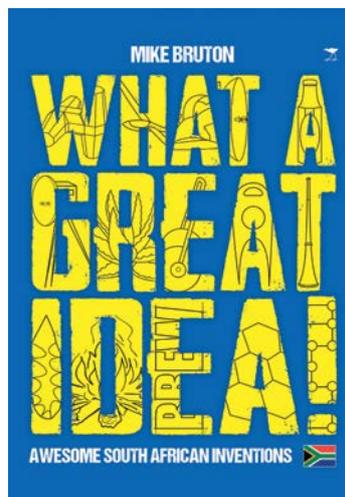


Trevor Wadley using a whirling hygrometer to measure humidity while demonstrating his tellurometer in England in 1957.

commemorate the 25<sup>th</sup> anniversary of his invention of the tellurometer. Sadly, he died of cancer at the age of 61. His tombstone reads, "Trevor Lloyd Wadley. Philosopher, Scientist, Beloved Family Man".

Other important South African inventions include:

- The CATscanner, a three-dimensional X-ray device separately invented by South African Alan MacLeod Cormack and British electrical engineer Godfrey Hounsfield, for which they shared the Nobel Prize for medicine and physiology in 1979 (see *Quest* 15.2)
- The digital laser, the first laser with a beam that can be shaped digitally using a hologram, developed in 2013 by Sandile Ngcobo for his PhD from the University of KwaZulu-Natal under the supervision of Prof. Andrew Forbes, based at the CSIR in Pretoria
- The Kreepy Krauly, the first commercially successful swimming pool vacuum cleaner, invented by Belgian immigrant Ferdinand Chauvier in 1951.

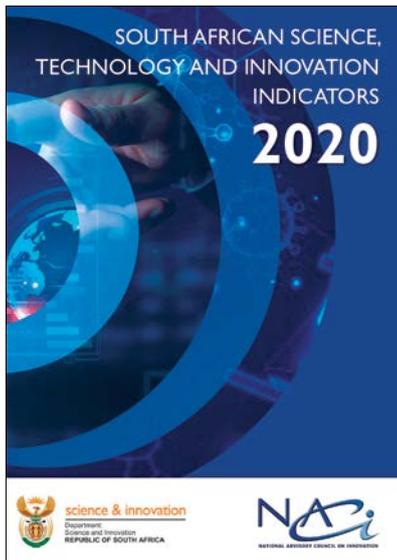


More information on these and over 700 other South African inventions can be found in Mike Bruton's book *What a Great Idea! Awesome South African Inventions*, published by Jacana Media in 2017.

*Prof. Mike Bruton is a former head of the Department of Ichthyology and Fisheries Science at Rhodes University, and was the founder and*

*Director of the MTN ScienCentre in Cape Town. Apart from his many scientific publications, he has written numerous popular articles and books and is a regular guest speaker at conferences and societies.*

# Science, Technology and Innovation Indicators Report 2020



Urgent steps need to be taken for South Africa to realise its economic growth and human development targets, and to place the country where it ought to be among the world's nations. This sentiment emerged during the release of the 2020 South African Science, Technology and Innovation (STI) Indicators Report, which reveals that the current state of STI in South Africa is less than ideal.

The online launch of the report on 28 August 2020 was accompanied by a policy forum on the state of innovation in the country. This included a presentation on the reviews of the National Research and Development Strategy (NRDS) and the Ten-Year Innovation Plan (TYIP), as well as a presentation on the Agricultural Business Innovation Survey 2016–2018.

The gaps identified in the STI Indicators Report provide a starting point for roleplayers to take South Africa's national system of innovation forward to meet the country's STI and development targets.

In producing the annual report, the National Advisory Council on Innovation (NACI) reviews the state of STI in South Africa over time and in a global context. This year's report reflects progress on some indicators, while pointing to areas of concern. Although South Africa's research institutions, such as universities and science councils, have steadily increased scientific publications over the past few decades, more recent performance indicates a decline. South Africa's publications per million of the population decreased from 371 in 2017 to 360 in 2018.

Most of the doctoral degrees produced in South Africa are in the field of the natural and agricultural sciences, with 1 051 doctorates produced in 2018. Only 7% of doctoral degrees produced are in the field of engineering.

Increased funding of universities contributed to an increase in the number of postgraduate students. The number of master's degrees increased from 6 460 in 2013 to 8 610 in 2018, while the number of doctoral graduates increased

from 2 051 in 2013 to 3 307 in 2018. The report suggests that, if the underlying forces during the past period remain intact, the number of doctoral graduates will reach the target of 5 000 per annum by 2030, with partnerships between science councils and universities contributing to the significant enrolment and graduation of both master's and doctoral candidates.

Although unemployment is lower among those with higher levels of education, unemployment of those with master's and doctoral degrees increased from 2.4% in 2018 to 2.8% in 2019.

"We are now looking at a point in this country where we have never had so many highly skilled people unemployed. It is a travesty, and the youth dividend is definitely at risk," said NACI Council Member and CEO of the Water Research Commission, Mr Dhesigen Naidoo. He added that, given South Africa's current structural socio-economic challenges, the country could not afford to have even a single unemployed graduate.

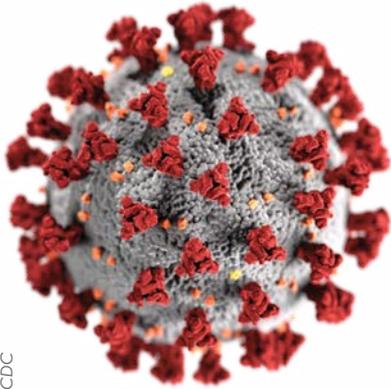
Discussing the reviews of the NRDS and TYIP, Prof. Johann Mouton, Director of the Centre for Research on Evaluation, Science and Technology at Stellenbosch University, said the original objectives of the technology-related strategies – to contribute towards the transition to a knowledge-based economy, to improve the sector's competitiveness through advanced manufacturing and innovation, and to leverage resource-based industries – were still valid. What had changed over time, he said, was the introduction of new technological initiatives in areas such as fluoride-based electrolytes, additive manufacturing and advanced materials.

"Technology changes are fast-moving and are often linked to new challenges resulting from fundamental shifts in social dynamics. It would thus be prudent for the Department of Science and Innovation (DSI) to revisit its current portfolio of technology programmes, in light of recent global developments as well as the recommendations of the Research Foresight Exercise."

He also urged the DSI to undertake an in-depth review of existing funding instruments targeting business and innovation in order to achieve optimal coordination and efficiency.

The full STI Indicators report can be downloaded from: <http://www.naci.org.za/index.php/south-african-science-technology-and-innovation-indicators-report-2019-2/>

*Issued by Department of Science and Innovation*



CDC

# Science, Technology and Innovation take on COVID-19

The first National COVID-19 Conference, which took place via the Zoom online platform on 31 July 2020, showcased the variety of ways in which science, technology and innovation are being harnessed for South Africa's response to the disease.

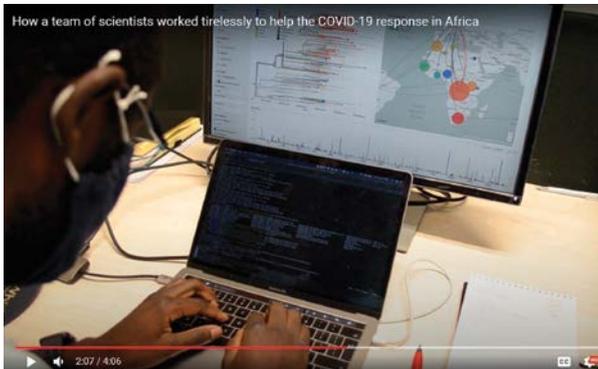
The conference, which lasted a little under six hours, began with an opening session of addresses by various dignitaries, including President Cyril Ramaphosa (delivered on his behalf by Dr Blade Nzimande), three government Ministers and the Director-General of the World Health Organisation (WHO), Dr Tedros Adhanom Ghebreyesus. This was followed by three panel sessions with experts and leaders presenting on health research – including innovations in therapeutics, diagnostics, testing and tracking – data modelling and analysis, and economy and social recovery.

During his opening address, Minister of Higher Education, Science and Innovation, Dr Blade Nzimande, gave an overview of the initiatives being fast-tracked by the

Department of Science and Innovation (DSI) to support the government's response to the COVID-19 crisis. These initiatives include the following.

## Deploying DSI-funded infrastructure to expand testing for COVID-19

For example, the Centre for Proteomic and Genomic Research – a non-profit organisation based in Cape Town – has validated various testing protocols and undertaken risk assessments according to WHO guidelines, and will install a laboratory information management system as required by the National Health Laboratory Services (NHLS). The KwaZulu-Natal Research Innovation and Sequencing Platform (KRISP), in partnership with the Centre of AIDS Programme for Research in South Africa (CAPRISA) and the Africa Health Research Institute, have validated the quantitative polymerase chain reaction (qPCR) and sequencing protocols from two manufacturers for COVID-19 testing. In addition, the Council for Scientific



KRISP

The KwaZulu-Natal Research Innovation and Sequencing Platform (KRISP) started performing qPCR testing with CAPRISA in March as part of a sentinel population cohort to determine when SARS-CoV-2 infections were first seen in South Africa. In July it tested thousands of samples to help clear the NHLS qPCR backlog. KRISP also began whole genome sequencing of the virus in April, and by the end of August had sequenced over 1 000 genomes. These and other KRISP initiatives are detailed in a news item and video called 'How a team of scientists worked tirelessly to help the COVID-19 response in Africa' on the KRISP webpage: <https://www.krisp.org.za/covidnews.php>.

and Industrial Research (CSIR) labs were repurposed to do testing in support of government's drive for a massive roll-out of testing.

### Biomanufacturing of molecular biology enzymes, reagents and testing kits

Local supplies of reagents and kits for COVID-19 testing are being developed through DSI-funded spin-out companies, centres of excellence, and various other programmes and initiatives to ensure security of supply, local manufacturing, and the creation and preservation of jobs. At the time of the conference, this work was at the South African Health Products Regulatory Authority (SAHPRA) accreditation stage, although approval had already been granted in some cases, with certain products having been ready for use in May.



Prior to lockdown, chemists at InnoVenton – Downstream Chemicals Technology Station at Nelson Mandela University had produced a first batch of 2 000 litres of sanitiser for the campus community. A further 1 500 litres were produced once more raw material was sourced. A service was subsequently offered to test the percentage alcohol content in hand sanitiser for other producers. By 20 August InnoVenton had produced almost 14 000 litres of hand sanitiser and had conducted 62 analytical tests for 21 different customers.

### Coordinating efforts for a local COVID-19 vaccine manufacturing plant

The DSI has convened a COVID-19 Vaccine Production Task Team that includes the Technology Innovation Agency (TIA), the Department of Trade, Industry and Competition (DTIC), the South African Medical Research Council (SAMRC), academia as well as local vaccine and adjuvant manufacturers Biovac (which is 47.5% government-owned) and Afrigen (which has Industrial Development Corporation investment). The aim is to get South Africa into a state of readiness to manufacture an approved COVID-19 vaccine locally.

### Providing technical support for the National Ventilator Project

The National Ventilator Project (NVP) was set up to coordinate and secure a supply of locally manufactured ventilators. The Solidarity Fund approved R250 million for the production of 20 000 non-invasive ventilators. Four potential suppliers were selected, including the CSIR, which was contracted to manufacture 10 000 non-invasive CPAP ventilators.



Prof. Ed Rybicki heads the University of Cape Town's Biopharming Research Unit (BRU), which has been awarded funding for a project to develop reagents for COVID-19 rapid test kits. The process relies on RNA made in plants using the BRU's proprietary plant virus-derived expression systems.

### Developing personal protective equipment (PPE)

In the first month of lockdown, the Product Development Technology Station at the Central University of Technology (CUT) produced two prototypes of a reusable mask that forms a tight seal around the mouth and nose, making it suitable for clinicians working in the 'hot zone', such as when intubating or suctioning a COVID-19 patient. The eNtsa innovation hub at Nelson Mandela University (NMU) is using additive manufacturing (3D printing) for face shield frame design and printing modifications to enable clinicians to easily replace standard A4 transparent sheets without the need for holes and adhesives. The designs had been made available through open-source networks.

### Supporting good hygiene practice

Many of the universities have been producing hand sanitiser, with some starting even before lockdown began. By 20 March, for example, the Technology Station in Chemicals at Tshwane University of Technology (TUT) had distributed the first 1 500 units of 15 ml bottles for individual use to TUT campuses. On the same day, production began at Rhodes University's Faculty of Pharmacy, which subsequently distributed thousands of litres to hospitals and other care facilities in the Eastern Cape, and also taught staff of organisations working in rural communities how to make sanitiser.

The CSIR-supplied ventilator is a CPAP – a Continuous Positive Airway Pressure device. It provides a mild level of oxygenated air pressure to keep the airways open, which assists with breathing.





CSIR

The CSIR LIFE (Lung Inspiratory Flow Enabler) CPAP ventilator was designed and produced by the CSIR in collaboration with a number of industry and manufacturing partners, with testing conducted at UCT's Medical Devices Laboratory to obtain approval and licensing by the South African Health Products Regulatory Authority (SAHPRA).

## The National Ventilator Project

During the conference, more detail on the National Ventilator Project was provided by Minister of Trade and Industry, Ebrahim Patel. He explained that under normal circumstances hospitals have an adequate supply of imported ventilators, which are used to supply oxygen to the lungs of severely ill patients. The ventilators range from ambu-bag resuscitators and nasal cannulas to non-invasive Continuous Positive Airway Pressure devices – known as CPAPs – and invasive ventilating machines. Of course, demand for ventilators soared worldwide in the first quarter of the year, due to the COVID-19 pandemic.

“In April this year, hospitals reported that they were unable to source ventilators on global markets. Minister Nzimande and I then decided to initiate the National Ventilator Project,” he said. “We appointed one of our top agencies, the South African Radio Astronomy Organisation (SARAO), to serve as project managers, given their world-class systems integration and systems engineering capabilities. These same scientists and engineers had delivered some of the technologies for the Square Kilometre Array project in the Northern Cape – the world’s largest radio telescope project with the power to peer deep into the cosmos and to shed light on the mysteries of the universe.”

A national call was put out, inviting proposals for the development and manufacture of CPAPS, as critical-

care physicians had advised that these had the greatest potential impact on saving lives.

“The response we received was phenomenal. Nearly 100 individual proposals were received,” continued Minister Patel. “These were thoroughly evaluated by the engineers and scientists at SARAO to ensure compliance with international standards for ventilators, usability in our hospitals and medical facilities, and to fully leverage South African manufacturing expertise. We needed a machine that could be used as easily in a private hospital in Sandton as in a field hospital in the Eastern Cape.”

Prototypes of the most promising proposals were built and tested, first in the laboratory and then in a hospital, to ensure compliance with the stringent requirements of the South African Health Products Regulatory Authority (SAHPRA). Funding was obtained from the Solidarity Fund, which was created in March as a donation platform for South African citizens and businesses to assist in addressing the challenges of the COVID-19 crisis.

- On 24 August, 36 ventilators were delivered to Charlotte Maxeke Academic Hospital in Johannesburg. These were part of the first batch that would be distributed to 60 hospitals countrywide. By mid-September, some 4 000 units had been delivered, at a cost of about R12 500 each.

# TRADITIONAL MEDICINE FOR COVID-19

The sensational claim on 20 April by Madagascar's president, Andry Rajoelina, that a tonic made from sweet wormwood could cure and prevent COVID-19 caused quite a stir, but it also put South Africa's own wormwood species under the spotlight.

*Artemisia afra* is one of our most widely used indigenous medicinal plants, known as African wormwood, umhloniyane, lengana, zengana and wilde-als. Its leaves have long been used as a traditional medicine for coughs, colds, flu and fever, amongst other ailments. The Madagascar product, developed by the Malagasy Institute for Applied Research and marketed as COVID-Organics, is made from *Artemisia annua*, which originates in Asia and eastern Europe but has become naturalised in many other parts of the world.

Several African countries ordered supplies of the product following Rajoelina's pronouncements, but health authorities soon issued cautions. Madagascar's own Academy of Medicine (ANAMEM) noted that scientific evidence had not yet been established, and there was a risk that the product could damage the health of the population. The French National Academy of Medicine weighed in too, advising against the 'reckless use' of *Artemisia*-based products for the treatment of COVID-19 until they had been properly studied. The World Health Organisation's Regional Office for Africa (WHO AFRO) issued a more measured statement. "Africans deserve to use medicines tested to the same standards as people in the rest of the world. Even if therapies are derived from traditional practice and natural, establishing their efficacy and safety through rigorous clinical trials is critical," it noted.

Apart from concerns about side effects, it was feared that people would neglect COVID-19 preventative measures such as handwashing, mask-wearing and social distancing if they believed they were protected by the traditional medicine.

More importantly, COVID-Organics and other products made from *Artemisia annua* may indirectly increase the threat of malaria by reducing the effectiveness of drugs used in its treatment. The plant is the main source of artemisinin, and artemisinin-based combination therapies (ACTs) are the standard treatment for uncomplicated cases of malaria. The WHO warned in 2019 that widespread consumption of *Artemisia annua* products will mean that many people have sub-therapeutic levels of artemisinin in their blood, which will hasten the development and spread of artemisinin resistance – already a major problem in south-east Asia and starting to emerge in Rwanda.



Our indigenous species, *Artemisia afra*, does not contain artemisinin. The Minister of Health, Dr Zweli Mkhize, and a number of medical experts from academia have said that while it should not be viewed as a cure for COVID-19, there is no harm in using it in the traditional manner. It might provide some relief of symptoms for those infected with the SARS-CoV-2 virus, but the rush to take it as a preventative measure by people not familiar with the optimal dosage reportedly resulted in uncomfortable side effects, mainly nausea. Studies on the plant's essential oils have also revealed varying levels of thujone, the toxicity of which is still subject to scientific debate.

Numerous lab-based studies to isolate and test compounds in *Artemisia afra* have taken place over the past two decades, both in South Africa and further afield. On 8 July, Minister of Higher Education, Science and Innovation, Dr Blade Nzimande, announced that a research team was now investigating several South African herbs and formulations with documented evidence for treatment of respiratory infections, signs and symptoms – including *Artemisia afra* – as possible immune-modulators and anti-coronavirus therapeutics. The Department of Science and Innovation had reassigned R15 million from existing indigenous knowledge (IK) projects to support COVID-19 interventions, and had submitted a proposal for additional funding, especially for clinical studies, SMME support cultivation, agro-processing and job creation. He added that the department's Decadal Plans envisage the establishment of an IK-based Bio-Innovation Institute, which will be a precursor to Africa's first plant-based pharmaceutical industry.

Ithimba labacwaning liphanya ngosizo lomhloniyane kubantu abanegciwane le COVID-19.

Translated by Zamantimande Kunene



## Inspirational Young Women in Science

The National Research Foundation (NRF) celebrated Youth Month in June 2020 by inviting students and researchers to tell their stories. During the month, 30 profiles were

shared via the NRF's social media channels. Here, *Quest* presents two of these profiles, featuring young scientists who got their start at the University of Zululand.



### Thuthukile Charmane Khumalo

*Miss Thuthukile Charmane Khumalo is a PhD student registered at the University of the Witwatersrand, but for research and supervision purposes is based at NRF-iThemba LABS (an acronym for Laboratory for Accelerator-Based Sciences). She has received funding from the NRF from her honours degree up to her current PhD studies.*

I grew up in Soweto, Gauteng, and later moved to the Umzinto area on the KZN South Coast. I come from a family of five: three sisters and one brother. I matriculated

at Sihle High School, Malangeni, which is in the rural area. I am a very passionate and ambitious human who is always curious and keen to learn new things. I enjoy reading, which is what I spend most of my time doing. This really helped me academically – I wouldn't stop reading where the lecturer stopped in class, but would read further on my own. I was always working hard because it's hard not to when one is passion-driven.

As a curious individual, I always had questions about how everything on Earth came about. Why? How is it the way it is? How far can we divide things? So, as I was doing my matric, I came across an article in the community library that was talking about a lady named Marie Skłodowska Curie. Her story fascinated me so much that I did more research and, ever since that day, she has been my role model. Whilst doing my research about this lady, I somehow realised that for me to have an idea of answering the questions that I always had, I would have to study nuclear physics. And this is how I ended up in nuclear physics!

I did my undergraduate degree (physics and chemistry), honours (physics), and master's (experimental nuclear physics) at the University of Zululand. I did my honours and MSc under the MANUS/MATSci NRF programme, which is done through the University of Zululand and the University of the Western Cape, both of which are described as historically disadvantaged universities. This didn't stop me from pursuing my dream and excelling.

Coming from a historically disadvantaged university, I've had to teach myself a lot of things, but I also make sure that I ask questions so that I learn from the people around me. For example, programming (or coding) is one of the things I had to teach myself as it is an essential skill in this field and also in the era that we are living in (4IR). I also had to put myself first and make decisions that were for me, and not listen to the many voices around me telling me which career path I should take – this was not an easy

thing to do as support, especially from family, is important. For my MSc, my research was in experimental nuclear physics, where I was doing a conceptual (simulations) design of a new detector to be used with the K600 high-resolution magnetic spectrometer at NRF-iThemba LABS in Cape Town. This is part of a bigger project at the lab. This work was presented in both local and international conferences and workshops.

I've just started my PhD and my research focus is still nuclear physics – I am studying a phenomenon known as the 'pygmy dipole resonance'. The study of this phenomenon in nuclei also has an astrophysical importance; for example, it helps provide input for astrophysical models that are used to predict the different processes governing the abundance and synthesis of the different elements we see on Earth.

My research will contribute to the body of knowledge of the nuclear physics field and might lead to further studies arising from the results. This will mean a lot for the nuclear physics community in Africa.

**If I could invite any three researchers – living or deceased – to a dinner party, I would pick:**

- Retief Neveling (my MSc supervisor): I would invite him because he is my role model and I really admire his

work ethic. He is a very knowledgeable individual and one can learn a lot from him.

- Marie Skłodowska Curie (my everyday motivation): Her experience and success in the field of science is a true definition of 'against all odds'. I have so many questions to ask her, such as what kept her going, what made her continue with her work despite the lack of recognition and support from the then physics community?
- Richard Feynman: I believe he was the greatest teacher of all time and – paraphrasing his words – he said that if you can't explain or teach something to someone, it means you don't understand it fully yourself. I would also learn a lot from him. I would definitely also want to know about how he feels about the development that has been done in science, specifically in the field of physics.

**What do I hope to achieve in the future?** Make a major contribution to nuclear physics or physics as a body of knowledge, and perhaps win a Nobel Prize. (It doesn't hurt to dream!)

**My advice for young people who are considering a career in STEM** is to never stop asking questions. There is no such thing as a stupid question! Lastly, find a passion and pursue it.



### Xolile Mbuyazi

*Xolile Mbuyazi is a DSI-NRF intern under NRF-SAEON, the South African Environmental Observation Network. She also received funding from the NRF for her honours studies in 2018.*

I grew up in northern KwaZulu-Natal, in a town called Mtubatuba. I moved there after staying with my aunt in Empangeni for the first few years of my childhood. I then

moved to Mtubatuba to stay with my grandmother in a house that was always packed, and always filled with love and laughter. I stayed with my grandmother until I was in Grade 10, attending Mtubatuba High School. I had to move with my dad after my grandmother sadly passed on.

I fell in love with science when I was still in high school – I really enjoyed life sciences and agriculture. That was until I went to university, which is where I was introduced to hydrology.

I started my degree at the University of Zululand in 2014, completed it in 2017 and registered for an honours degree in 2018. Thanks to the NRF, I could afford to pay for my honours. In 2019, I started a DSI-NRF internship, hosted by NRF-SAEON at the Grasslands-Forests-Wetlands node based in Pietermaritzburg.

Growing up in Mtubatuba's KwaMsane township, we did not have water in our taps most of the time, and yet the Mfolozi River was flowing. So I was curious as to why this was happening, and since no one around home could help me get those answers, I figured what better than hydrology to help me answer those questions. Having to go looking for water all around the township after school with my cousins (just to have water for basic needs) served as a motivator. I therefore chose a career in hydrology, with the hope that one day I could help my community and other rural communities.

Growing up, I wanted to be a medical doctor because I loved science and I didn't know a lot about scientific careers, but now I am glad I found hydrology. I have had

to overcome a lot of obstacles in my life to get to where I am today, and I still have a lot of obstacles to overcome. I have had people telling me I can't do it, but I never gave up on myself.

My research focus is groundwater hydrology, which might change or be more focused as I am planning on starting my master's in 2021. Currently, however, I am working on an erosion project in Cathedral Peak research catchments as part of my intern project with NRF-SAEON. I would like to believe that, one day, my research will help my community understand the reasons behind the water situation – to get solutions as to why the taps are dry while the rivers are flowing, and to help other communities in South Africa and Africa – because that is the whole reason I chose this career.

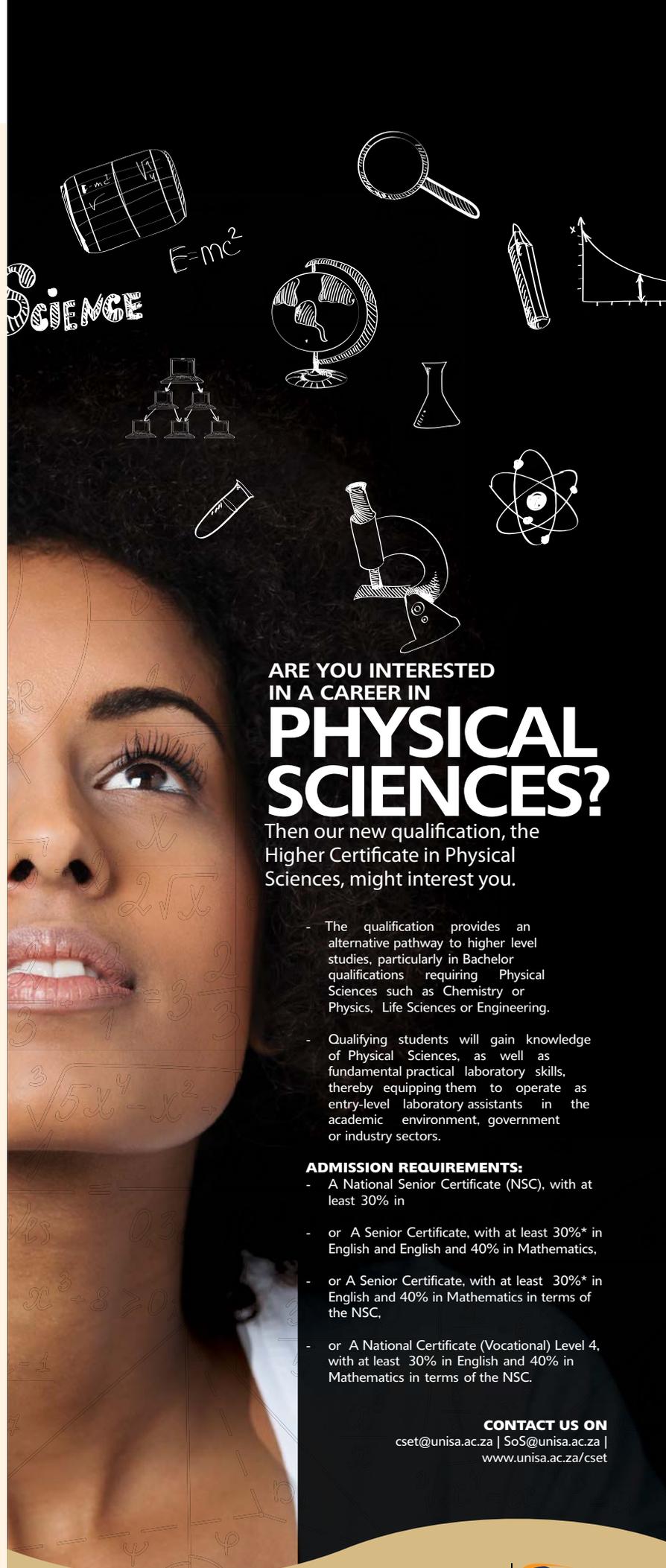
**If I could invite any researcher to a dinner party,** I would pick Dr Ricky Taylor, my honours supervisor. I would invite him because he was the first researcher who believed in me, even when I didn't believe I could do it. Whenever I think of my future as a researcher, I think of the one person who believed in me and still does. It would be interesting to pick his brain about a lot of things besides my career as a researcher.

**My advice for young people who are considering a career in STEM?** The greatest advice I have is for a young black woman like me who is trying very hard to break through into this big scientific world. I would say to her: "Do not be scared, you have the potential and the capability of becoming whoever and whatever you want." There are generational curses and people telling us that we do not belong or that we can't do it. I would say to never give up on yourself, even when you feel like the odds are stacked against you. There are going to be many late and sleepless nights ahead, but do not give up. There is a young girl out there who will, one day, look at you and say: "I want to be like her when I grow up."

**What do you hope to achieve in the future?** I want to get my MSc and PhD. I want to be a known researcher in my field and publish articles. After all that, I want to start a foundation that helps young girls from townships and rural areas like me who are interested in STEM, a foundation that will deal with helping girls realise that there are occupational choices other than that of a teacher or a nurse. There is a whole world out there to explore!

The rest of the Youth Month profiles are available at <https://www.nrf.ac.za/tags/youth-month>

The NRF also published another 28 profiles on 'Women at the heart of STEM' in August to celebrate Women's Month, available at <https://www.nrf.ac.za/features-0>



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Alberto Valenciano

## Who's who in the prehistoric zoo

**Dr Alberto Valenciano Vaquero with the West Coast Fossil Park's models of *Sivatherium hendeyi*, one of three extinct giraffe species found at the Langebaanweg palaeontological site.**

Palaeontologist Dr Alberto Valenciano Vaquero came to South Africa from Spain in 2018 on a two-year postdoctoral fellowship hosted by the Iziko South African Museum and the University of Cape Town. His mission was to study the museum's collections of fossil carnivores from the palaeontological site of Langebaanweg, situated about 120 km north of Cape Town on the west coast. In June 2020 this research was prominently featured in the news, with headlines about 'wolf-sized otters and leopard-sized wolverines', following the publication of a scientific paper on giant mustelids co-authored by Alberto and Dr Romala Govender, Iziko's Curator of Cenozoic Palaeontology, Research and Exhibitions.

Alberto returned to Spain shortly thereafter to take up a new fellowship at the University of Zaragoza, but on 15 July he presented a webinar as part of a series organised by the Society of Spanish Researchers in South Africa (ACE South Africa) in collaboration with the Spanish Embassy. His presentation, titled "The West Coast of South Africa five million years ago: short-necked long-'horned' giraffes, sabretooth cats, and other beasts", revealed that the Langebaanweg site is a veritable 'zoo' of prehistoric animals.

Alberto explained that between 5.96 and 5.33 million years ago, Africa collided with Europe and the Mediterranean Sea dried out, allowing animals to easily migrate between Eurasia and Africa. At the start of the Pliocene, the sea level rose again, so the Langebaanweg site – now 13 km inland

– would have been very close to the coastline 5.2 million years ago. In fact, it would have been part of the estuary of the Berg River, which today flows into the sea a little further north, at St Helena Bay. The climate would also have been a bit warmer then, so the area would have included riverine forests, grasslands and tidal zones. This provided a rich habitat for a diverse fauna, but it's also clear that some of the fossils at the site are from animals washed downstream from further inland and then entombed in the estuarine mudflats.

The presence of important fossils at the site was first recognised in the late 1950s. At the time it was a quarry, where phosphate rock was mined for fertiliser. But it was only in 1964 that palaeontological research was initiated there, under the leadership of Dr Brett Hendey of the South African Museum (now part of Iziko Museums). Over the next two decades he published extensively on the team's numerous fossil finds, and it became clear that the site has one of the world's richest and best-preserved Neogene (late Miocene/early Pliocene) mammal assemblages.

The mine was eventually closed in 1993 but its owner, Samancor, entered into a public-private partnership with Iziko Museums to form the West Coast Fossil Park, which opened in 1998. The quarry's old office block was renovated into a visitor centre with an informative display area, and research excavations at the site have continued. There is still much to be learnt from fossils unearthed at the site in the past though.



Alberto Valenciano

**Dr Romala Govender, who co-authored the scientific paper on Langebaanweg giant mustelids, at the bonebed displayed at the West Coast Fossil Park.**

Alberto gave a thorough overview of the marine and terrestrial vertebrates represented by fossil finds at the site to date. For example, more than 10 000 bones of birds have been studied by various researchers, and these have been shown to belong to 90 different species.

The herbivores include three species of giraffe, the most important being the short-necked long- 'horned' giraffe – the 'horns' are in fact ossicones formed from ossified cartilage. Its name is *Sivatherium hendeyi*, just one of a number of species named in honour of Hendey (the genus name refers to the fact that the type specimen, *Sivatherium giganteum*, was found in the Siwalik region of the Himalayan foothills in the 1830s). A bonebed in one of the ancient river channels at Langebaanweg is dominated by the giraffe's bones, representing some 500 individual animals.

Other herbivores include, among others, three species of elephants and a huge diversity of bovids, but Alberto's interest lies in the carnivores, which are divided into two suborders, the cat-like Feliformia and the dog-like Caniformia. The former include the cat, hyaena, mongoose and viverrid (genets and civets) families, and all of these are represented at Langebaanweg. Most exciting are the three or possibly four species of sabretooth cat. Alberto explained that unlike modern-day lions that clamp their jaws over the throat of their prey to suffocate it, the elongated canines of the sabretooths would pierce the blood vessels and oesophagus so that the prey would die in seconds rather



Alberto Valenciano

**The extinct giant otter had a more robust dentition than the African clawless otter found in the Cape today.**

## CURRICULUM CORNER

### LIFE SCIENCES: GRADE 10

History of life on Earth



Maggie Newman, GSSA and Wits University

**Maggie Newman's depiction of the Langebaanweg ecosystem five million years ago shows a gigantic wolverine snarling at a primitive hyena as it feeds on a giant pig, while a bear looks on.**

than minutes. This minimised the risk of injury to the predator.

The Caniformia suborder includes dogs, bears, wolves, foxes, jackals, raccoons, badgers, seals and mustelids. Alberto noted that mustelids are his "favourite animal ever", and are the largest living family within the Carnivora, comprising 57 species of weasels, ferrets, badgers, wolverines, otters and martens. He explained that a group of extinct mustelids are called giant mustelids because they are twice the mass of the largest terrestrial form, but they're poorly understood because they are scarce in the fossil record. In the 1970s Hendey identified bone material of a giant otter found at Langebaanweg as *Enhydriodon africanus*, but other researchers subsequently recognised it as a new species and transferred it to a different genus, with the name *Sivaonyx hendeyi*.

In their recently published paper, Alberto and Romala described new material and also re-examined the previously described material. They hypothesised that *Sivaonyx hendeyi* had semi-aquatic locomotion similar to that of the living African clawless otter and Asian small-clawed otter, but with some digging capability too. Its robust dentition suggests its diet was based on armoured catfishes, molluscs, crustaceans or even bones.

They also confirmed that Langebaanweg's wolverine, *Plesiogulo aff. monspesulanus*, is a different species to that of the large-bodied *Plesiogulo botori* from Kenya and Ethiopia, which means that there were at least two large species of wolverine in Africa at the end of the Miocene and beginning of the Pliocene. On the basis of its stout bones and massive teeth, it's likely that the Langebaanweg species was the size of a leopard, and acted as an ambush predator on the grassy plains.

Alberto finished off his webinar presentation by discussing the other caniforms found at the site, including at least 11 individuals of an extinct bear. It was a fascinating virtual tour of the Langebaanweg 'zoo'.

- For more information, see the open access paper by Valenciano and Govender at <https://doi.org/10.7717/peerj.9221>

# CANCER GENOMICS

Caroline Davis, CC BY 2.

*Annie Joubert explains how DNA technology is changing the face of cancer*

Cancer is ultimately a disease of DNA – mutations in your genome influence your risk of being diagnosed with it, and may determine what happens during the course of the disease. The advent of modern DNA technologies, and particularly next-generation sequencing, is rapidly changing the face of diagnostics and treatment.

The possibility of screening for DNA mutations in genes that may increase the risk of cancer, especially breast cancer, is advancing with the production of panel testing kits, some of which can target hundreds of genes. There is no doubt that the development and roll-out of these tests will save lives.

Today the complete genome sequence of a cancer patient, together with the profile of genes being activated and deactivated, can be obtained. This genomic picture can be used to assess a patient's cancer risk and progression, and to design tailor-made treatment strategies.

There are two approaches to analysing mutations in DNA: tests that analyse the mutations a person was born with and which assess the risk of being diagnosed with cancer (germline cancer susceptibility analysis), and tests that analyse the mutations in tumours or other sources in

cancer patients (somatic mutation analysis). Cancer susceptibility analysis may help to determine whether someone should be examined for cancer more regularly with additional screening tests, whereas

somatic mutation tests may help oncologists understand what happened when cancer developed, and guide them in recommending further testing and treatment.

The genome may be studied for mutations using different approaches. Targeted chip-based analyses report the status of mutations only in positions previously known to be important. This includes testing for mutations at genome sites known to increase cancer risk, mutations related to the prediction of cancer outcome or mutations that guide oncologists in designing the best treatment approach.

When evaluating the genome sequence of an individual, next-generation DNA sequencing approaches are used, and novel or previously less-studied mutations may also be detected. These types of approaches include whole genome sequencing (all DNA), whole exome sequencing (sequencing the sections of the genome that make proteins) and targeted sequencing (where genes or other non-protein-producing, but important, parts of the genome are selectively sequenced).

An additional type of analysis includes whole transcriptome sequencing, where messenger RNA molecules (which act from DNA to create a template for the production of a protein molecule) are sequenced and quantified to determine which genes are abnormally active or inactive. Also, duplications of sections in the genome can be analysed in the form of copy number variation, where the duplication of certain genes may lead to cancer.

Breast cancer is one of the most common forms of the disease in women – the lifetime risk of South African women getting breast cancer is one in 27. The role of many mutations in the BRCA1 and BRCA2 genes in breast cancer





Konrad Förstner-CC BY2.0

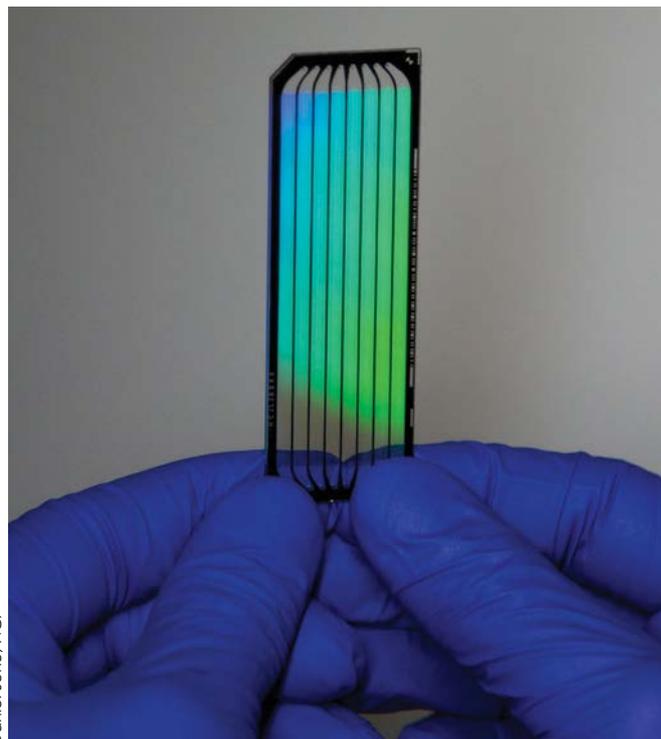
**The Illumina MiSeq is one of the most widely used next-generation sequencing platforms. It uses a double-sided, single-lane flow cell and reagent cartridge supplied in kit form.**

susceptibility has been well studied. These genes produce proteins involved in processes that repair errors occurring in DNA. If they do not function correctly, these errors may lead to the development of cancer.

Many other genes also play a role in determining the risk of breast cancer, albeit with smaller effects than BRCA genes. About 15 genes that have mutations more often than expected in women who are diagnosed with breast cancer have been identified. However, hundreds of other genes potentially play a role. In some instances, mutations do not act alone but lead to cancer only when they occur in concert with mutations in other genes.

The possibility of screening for DNA mutations in genes that may increase the risk of breast cancer is rapidly advancing as scientific companies are producing cancer panel testing kits, such as the Illumina TruSight cancer panel developed with Cancer UK, which analyses the sequences of 94 important cancer susceptibility-related genes (not only for breast cancer) and monitors for a series of other possible mutations that have been related to an increased risk of cancer. This is one of the smaller testing kits; others target hundreds of genes. There are also kits that may determine the specific mutations that took place in the tumour of cancer patients, as well as those that do not focus on the DNA sequence per se, but assess abnormal protein expression levels. The MammaPrint breast cancer assay analyses the levels of 70 different gene products that are used to help determine whether a patient should proceed with chemotherapy.

For individuals, access to advanced testing is typically through a cancer centre or an oncologist, who will arrange for a pathology company or specialised DNA analysis company to analyse samples, followed by subsequent consultations with an oncologist and a genetic counsellor. While a few years ago only BRCA1 and BRCA2 testing was commonly available, cancer centres – particularly in the USA, Europe and Asia – are now making regular use of large cancer susceptibility and somatic mutation testing panels. International consortia are building huge databases of



Daniel Sone, NCI

**A DNA sequencing flow cell.**

mutations in cancer patients and correlating the mutations to the choice of successful treatment methods.

As with most cutting-edge technologies, many of the new testing approaches are costly, not yet commonly available, have not yet been approved for clinical use in all countries, are not part of health insurers' benefits and are sometimes available only to patients that are included in large research trials. Still, the rapid development and roll-out of these tests are starting to save lives.

About 5–10% of cancers can be attributed to genetic inheritance. DNA mutations may occur for several other reasons after birth. These mutations may be triggered by risk factors such as tobacco products, alcohol consumption, diet, environmental pollutants, ultraviolet radiation, reproductive and hormonal factors, occupational exposures and infection-attributable cancers.

As Richard Dawkins said, "DNA neither cares nor knows. DNA just is. And we dance to its music." The dance between DNA and genomic research impacts our lives hugely. Advances in genomic research reveal the biology of disease and ultimately contribute to redefining our health management, today and in the future.

*Prof. Annie Joubert  is head of the Department of Physiology at the University of Pretoria. Her research focus is cancer cellular physiology. She studies cancer drug design and cancer cell signalling to identify targets for therapeutic intervention in the fight against cancer.*

*This article is an amended version of a news story originally posted on the University of Pretoria's website on 25 April 2020 to celebrate DNA Day, and republished with permission. [https://www.up.ac.za/news/post\\_2890798-dna-day-up-expert-on-how-dna-technology-is-changing-the-face-of-cancer](https://www.up.ac.za/news/post_2890798-dna-day-up-expert-on-how-dna-technology-is-changing-the-face-of-cancer)*



## Computer Science meets *The Arts*

In popular culture, computer scientists are often portrayed as techno-geeks who are glued to their screens, bashing away on their keyboards and glugging back energy drinks to keep them coding through the night. Yet computer science is in essence simply the use of computers to study information and solve problems. Here, *Quest* profiles two recent MSc graduates who applied their computer science skills to their personal interests.

### Ballet pose recognition

Margaux Fourie, a lecturer at the University of Johannesburg's Academy of Computer Science and Software Engineering, recently graduated with a master's degree in computer science. Her postgraduate studies gave her an opportunity to pursue her twin passions.

"As a computer scientist, I have a passion for solving problems, but simultaneously I've always loved and intensely pursued the athletic art form of ballet. At the start of my postgraduate studies, these two passions were introduced

to one another as I began research in pose recognition using computer vision," said Margaux.

Her journey to a master's degree was filled with unique challenges, adventures and wonderful opportunities. Some of the challenges were the limited datasets available for ballet, and a lack of experienced dancers available for capturing the required data. But the highlights included being accepted into an American professional ballet company's programme.

"Being accepted was a dream come true. With the blessing of the Faculty of Science, I was afforded the opportunity to train with this touring company that I've long admired. For nine months I was based in Jackson, Mississippi, in the USA, where I got to dance alongside a group of extremely talented people. It was an incredibly enriching experience that involved tours to Mexico and Cuba, along with opportunities to reach out to communities through dance. On top of that, I was surrounded by gifted dancers every day, which enabled me to capture a complete dataset for my research."

Upon returning to South Africa, Margaux had the daunting task of completing her dissertation, with only a few months remaining to the official deadline.

"It was a challenging yet extremely rewarding process to write up the research that took me on an adventure of a lifetime," she said. "The unwavering support I received from family and the Academy of Computer Science and Software Engineering made it possible to complete the study in time. I am grateful to UJ, the Faculty of Science and the Academy for generously granting me the opportunities that came along with the pursuit of this qualification."



Adam Liwinski, CC BY-NC 2.0

**Margaux Fourie**

Margaux jokingly pointed out that her master's graduation was scheduled for 1 April 2020 – April Fool's Day.

"True to that day's reputation, my graduation could not take place due to the national lockdown. But I am pleased to say that I still graduated virtually and got to celebrate the event with colleagues and loved ones digitally."

In July, Margaux presented her research in the virtual First International Conference on Artificial Intelligence in HCI (Human-Computer Interaction), which had been due to take place in Copenhagen. The resulting refereed paper, co-authored with her supervisor, Dustin van der Haar, proposes a feature importance study for determining which body parts play the most significant role in ballet pose recognition. The study is based on the use of OpenPose for feature extraction, together with Support Vector Machine, Random Forest and Gradient Boosted Tree classifiers.

### IsiZulu language processing

Research into isiZulu language processing earned Sibonelo Dlamini his MSc degree in computer science from the University of KwaZulu-Natal (UKZN), where he was supervised by Edgar Jembere and Anban Pillay.

Sibonelo completed his schooling at George Campbell School of Technology in Durban, after which he registered at UKZN for a degree in electronic engineering. He soon realised, however, that he was more keen on computer programming, and switched to a BSc in computer science. "As I progressed through my undergraduate degree, I fell more in love with the field of computer programming and have been ever since," he said.

After completing his BSc honours degree in computer science, Sibonelo progressed to master's level, focusing his research on natural language processing. This field of study combines programming, machine learning and language – three areas Sibonelo is passionate about. "It is exciting to do research in an area that is a key driver of the Fourth Industrial Revolution," he said.

In his research project, Sibonelo dealt with isiZulu, which is an agglutinative language. This means it has a complex internal structure, constituted by numerous morphemes – the smallest units in a language that have meaning. It is

**Sibonelo Dlamini**

therefore more difficult to develop language technologies for isiZulu than for English, which has a simpler internal structure. Sibonelo tested the hypothesis that incorporating information about the internal structure of words of an agglutinative language would improve performance on the Word Sense Disambiguation (WSD) task. This is a machine-learning task that determines the correct sense of an ambiguous word in text.

Sibonelo's research goes a long way towards helping maintain the relevance of isiZulu in the current information age. He explained that people would stop using languages if they could not use technologies for tasks like voice recognition, information retrieval and grammar-checking.

"The motivation for my study was to stop the migration of language preference from isiZulu to English," he said. "It will preserve the invaluable cultural heritage that the language represents for a large section of South African society, and retain access to indigenous knowledge, which is encoded in the language."

Sibonelo explained that developing language technologies for a language was important because it maintained the relevance of the language in the information age. "If we don't create space for indigenous African languages within this revolution, we may witness their rapid extinction and the erosion of African identity that will necessarily follow," he said. "Through my research, I hope to mitigate this potential hazard through the development of state-of-the-art technologies for agglutinative languages."

Sibonelo is currently continuing his research at PhD level, working towards creating an automatic speech recognition solution for isiZulu, since speech is becoming a ubiquitous means of interfacing with computers. His future plans are to work full-time as an academic because of his passion in both research and teaching.

*'Ballet pose recognition' issued by the University of Johannesburg*  
<https://www.uj.ac.za/newandevents/>

*'isiZulu language processing' written by Samantha Ngcongco for the University of KwaZulu-Natal's newsletter Ndaba Online, Vol. 8 Issue 19.*  
<http://ndabaonline.ukzn.ac.za/UkzndabaNewsletter/Vol8-Issue19-caes-grad>

# CODING EDUTAINMENT

**In July, almost 500 learners from 95 schools and organisations took part in a week-long virtual coding tournament that was both fun and informative.**

The tournament was organised by Prof. Jean Greyling and his team from Nelson Mandela University in Port Elizabeth, who have introduced more than 20 000 learners across the country to coding over the past three years. They normally do this by arranging workshops that use one of the three game-based Android apps they've developed to teach learners the basic concepts of coding without the need for a computer. Lockdown meant that those workshops could not take place, so the team adapted one of the apps, called BOATS, to allow learners to participate in events from home, even if they had no previous coding experience.

The level of coding in the BOATS game is based on the robotics curriculum of lower primary school grades, but the competitive nature of the app makes it fun even for FET Phase learners (grades 10–12). Players have to navigate a boat in a grid representing the ocean, removing plastic litter along the way, with extra points earned for correctly answering multiple-choice questions on plastic pollution in the marine environment. These questions and supporting tips, such as 'Say no to plastic straws', mean that learners are educated on marine pollution as well as coding.

New features added to the original game after lockdown include information on COVID-19 safety measures, and the fact that scores are emailed directly from the app to a central database. Prizes totalling more than R50 000 were up for grabs in the tournament, which kicked off on



Nelson Mandela Day – Saturday, 18 July – and ran until the following Saturday. During this time, 10 227 scores were submitted as the participating learners advanced through the different levels of the game.

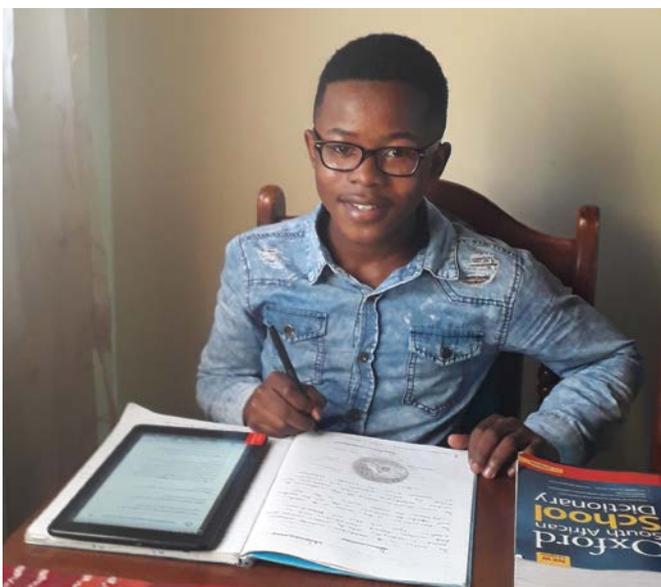
Ultimately, the single highest score was achieved by Grade 11 learner Zukhanye Swartbooi from Khulani Commercial High School in Mdantsane, near East London. He won a tablet for his efforts, as did Grade 9 learner Simamnkele Dekeda from Newell High School in New Brighton, Port Elizabeth. Simamnkele shared the second-highest score with more than 100 other learners, but also completed all 40 levels of the game and was the learner who submitted the most scores. Simamnkele had in fact been the overall winner in the first BOATS virtual tournament held in May, which involved only 180 learners from 30 schools.

Nearly 90 learners won 500 MB of free data each, and a number of cash prizes were awarded. For example, Park Primary School from Lenasia in Gauteng won R4 000 as the best participating school. Six schools won a TANKS coding school kit, which normally costs R3 000. Each kit contains seven lesson plans developed by a teacher, instructional videos for the different levels and coding concepts, the game solutions as well as eight sets of the TANKS game, which is ideal for a class of 40 learners split into groups of five.

TANKS was developed in 2017 by one of Prof. Greyling's computer science honours students, Byron Batteson. It uses tangible tokens, which look like puzzle pieces, and image recognition to move a battle tank around a grid. Learners have to arrange the tokens in a particular order to build the code, then take a photo of it with a smartphone camera. The image recognition internalises the code and executes the tank's movement on the smartphone's screen.

TANKS has 35 levels with increasing complexity and is more advanced than BOATS. Apart from the school kit, it can be purchased as a standalone game set for R150 plus postage, and is available for both iPhones and Android phones, whereas BOATS and the other game, RANGERS, are Android-specific. RANGERS uses the same tokens as TANKS and has the same level of complexity, but it has an anti-poaching theme and the target is to 'Save the rhino'.

Prof. Greyling says the team has received numerous awards and accolades for the games, and for making them available to disadvantaged schools through sponsorships. Most recently, he was invited to be a plenary speaker at the 2020 UNESCO Mobile Learning Week that was to have been



**Simamnkele Dekeda, a Grade 9 learner from Newell High School in New Brighton, Port Elizabeth, doing homework using the tablet he won in the coding tournament.**



**Muller du Plessis, a Grade 2 learner from Gill Primary in Somerset East, was one of 90 learners winning 500 MB of data.**

held in Paris in March, but the event had to be cancelled because of the COVID-19 pandemic.

In any case, he says, the feedback he receives from both learners and teachers is rewarding in its own right. During the BOATS tournament, learners sent numerous positive comments that were posted on the project's Facebook page – 'Games powered by Tangibl'. A teacher from Gobinamba High School, situated in a rural area outside Tsomo in the Eastern Cape, expressed heartfelt thanks to the team.

"My children now are developing a passion for computer science. They didn't even know of the career's existence!" said Ms Lusanda Maqungo in her message. "I am going to push forward too due to the motivation from the tournament! My principal and my colleagues are widely smiling, seeing potential in their kids."



**The TANKS game, played here by learners from a high school in Cala in the rural Eastern Cape, uses tangible tokens resembling puzzle pieces to build code.**



**TANKS can be purchased as a game set for both iPhones and Android phones.**

An IT teacher at the relatively well-resourced Alexander Road High in Port Elizabeth was equally complimentary. "During this time of lockdown, the tournament allowed our learners to be involved in constructive academic activity that improves their computational thinking, but is also great fun," said Ms Leanda Oosthuizen.

Byron Batterson is still a partner in the project, but he now works as a software development engineer for Amazon Web Services (AWS) in Cape Town. AWS was one of the sponsors of the BOATS tournament, making a number of prizes available and also helping the team honour their commitment to the beneficiary organisation they'd chosen for the event.

The tournament had been advertised as a fundraiser for the Port Elizabeth branch of SANCCOB – the South African Foundation for the Conservation of Coastal Birds – with the intention that R15 would be donated for every learner who entered. But the team had not anticipated the high number of entrants, and would not have been able to pay the R7 350 that the pledge added up to. Fortunately, AWS came to the rescue and provided additional sponsorship, allowing a donation of R8 725 to be made to SANCCOB. These funds would partly make up for the lockdown-related loss of income normally generated by SANCCOB's rehabilitation and education centre through entry fees, merchandise sales and its coffee shop.

The earlier virtual tournament in May raised R6 000, which was used by the Red Band Barista Academy to distribute free coffees to COVID-19 medical workers in the Port Elizabeth area as part of their Coffee4Heroes project.

- For more information, visit the Facebook page 'Games powered by Tangibl', or contact Prof. Greyling at [Jean.Greyling@mandela.ac.za](mailto:Jean.Greyling@mandela.ac.za).

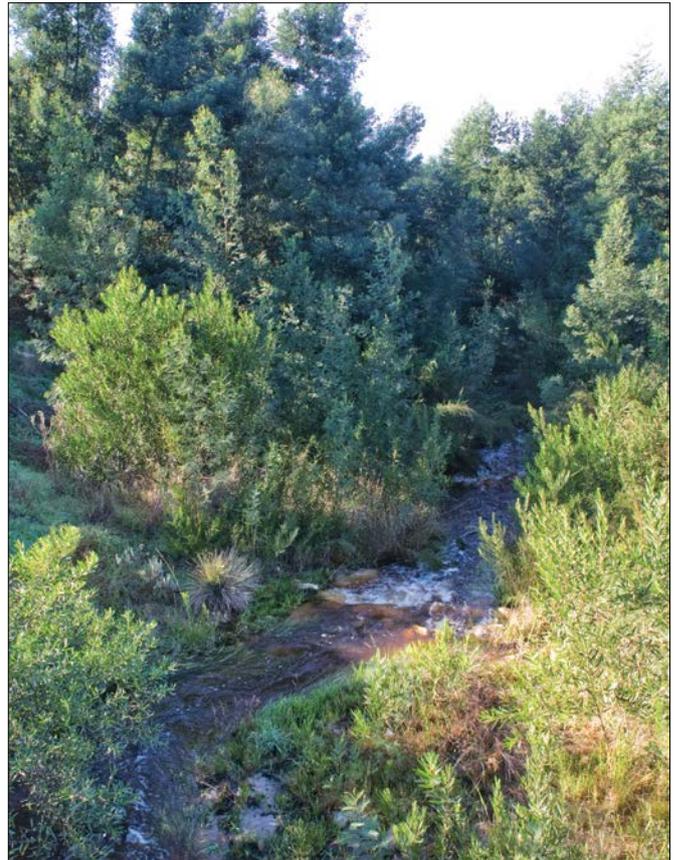
# Spotlight on INVADERS

A team of researchers from 13 countries around the world, including South Africa, have warned that the threats posed by invasive alien species are increasing. They say that urgent action is required to prevent, detect and control invaders at both local and global levels.

In an open access paper published in the journal *Biological Reviews* on 26 June 2020, they present a comprehensive overview of environmental change due to invasion by alien species, noting that the intention is to support global initiatives addressing the loss of biodiversity and ecosystem services. Their study found that the number of invasive alien species is increasing rapidly, with more than 18 000 currently listed around the world.

The escalation can be attributed to the increase in the number and variety of pathways along which species spread, and to the increasing volume of traffic associated with those pathways. Emerging pathways include the online trade in unusual pets as well as plants for ornamental horticulture, and the transport of species across oceans on rafts of plastic pollution.

The study also shows how other drivers of global change, such as climate change, land-use change, and international trade are exacerbating the impacts of biological invasions. For example, species transported by shipping can now thrive in new regions due to climate or ocean warming. And diminishing Arctic sea ice is expected to create a year-round passage between the Atlantic and Pacific Oceans by mid-century, allowing marine species to move between the two.



Sue Matthews

**By replacing indigenous shrubs and grasses on the banks of watercourses, invasive wattle trees increase erosion, resulting in siltation downstream.**

## Biological Invasions in South Africa

A comprehensive account of all aspects of biological invasions in South Africa has recently been published as an open access e-book. *Biological Invasions in South Africa* synthesises knowledge gained and lessons learnt over the past three decades, during which time government made a substantial investment in research and management relating to invasive species. Most prominent has been research on alien plants and the control efforts of the Working for Water programme, but the book deals with animals in terrestrial environments too, as well as plants, animals and pathogens in marine and freshwater environments.

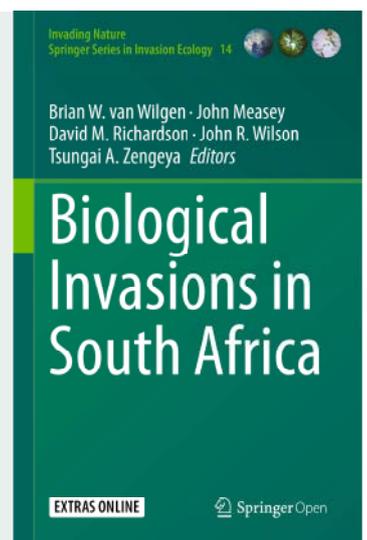
The 31 chapters are grouped into sections dealing with the drivers of invasions, the impacts of invasion, the management of invasions, new insights and the way forward, but they cover a broad range of topics, such as policy development and implementation, ecological theory and the social dimensions of invasions.

Since each chapter was written by multiple authors, more than a hundred researchers, practitioners and postgraduate students were involved. Lead editor, Prof. Brian van Wilgen from the Centre of Excellence for Invasion Biology (CIB) and the Department of Botany and Zoology at Stellenbosch University, says that it's hoped

the book will be used as a teaching tool and as a source of information for managers in the field, apart from being a key reference work for researchers. His co-editors were colleagues Prof. John Measey and Prof. Dave Richardson as well as fellow CIB members Prof. John Wilson and Dr Tsungai Zengeya of the South African National Biodiversity Institute (SANBI).

South Africa is considered a global leader in the invasive species field, so the experience documented in the book will likely also be of immense value to researchers, students, managers, and policymakers in other parts of the world.

The entire e-book or individual chapters can be downloaded at <https://link.springer.com/book/10.1007/978-3-030-32394-3>



Patrick Dugan. CC BY-NC-ND 2.0



**The Nile perch, introduced to Lake Victoria to improve fishing, is thought to have caused the extinction of 200 endemic species of cichlid fish.**

The impact of invasions on indigenous species is enormous, whether through predation, competition, habitat alteration or a variety of other mechanisms. An analysis of the 2017 IUCN Red List of Threatened Species database revealed that alien species contributed to 25% of plant extinctions and 33% of animal extinctions.

What's more,

annual environmental losses caused by introduced species in the United States, United Kingdom, Australia, South Africa, India and Brazil have been calculated at more than \$100 billion.

In South Africa, an assessment conducted for the book on biological invasions below listed 1 422 alien species that are naturalised or invasive. Some of these have serious impacts on ecosystems, such as the 'thirsty' alien tree species that take up large quantities of water.

"South Africa has invested heavily in a massive national programme focused on reducing the negative impacts of widespread invaders on ecosystem services, especially the delivery of water from catchments invaded by alien trees," says Prof. David Richardson of the Centre for Invasion Biology at Stellenbosch University, who was a co-author of the paper. "But action is needed more widely at both national and international levels in order to tackle the challenges effectively."

The authors stress that biological invasions can be managed and their impacts mitigated. They point to approaches that are working around the world and make specific recommendations for improved management. For example, the introduction of more stringent border controls, including X-ray machines and detector dogs, has led to a progressive decline in the rate of fungal plant pathogens entering New Zealand.

"As our knowledge about invasive alien species increases, the problems associated with biological invasions are becoming clearer," notes lead author of the paper, Prof. Petr Pyšek of the Czech Academy of Sciences and Charles University in Prague. "The threats posed by invasive alien species to our environment, our economies and our health are very serious, and are getting worse. Policymakers and the public need to prioritise actions to stem invasions and their impacts."

- The paper is available at <https://onlinelibrary.wiley.com/doi/full/10.1111/brv.12627>

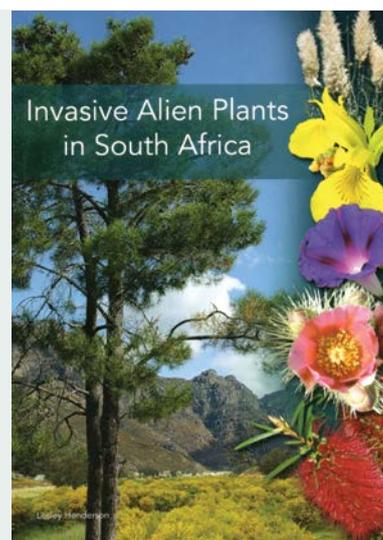
*Compiled from media releases issued by Stellenbosch University and University of Rhode Island*

### Invasive Alien Plants in South Africa

This book marks the culmination of the remarkable career of Lesley Henderson of the Agricultural Research Council – Plant Health and Protection (ARC-PHP). In 1979 she began conducting roadside surveys to identify and map invasive alien plants, racking up 150 000 km as she criss-crossed the country. The data she collected gave rise to the Southern African Plant Invaders Atlas (SAPIA) database, launched in 1994 as an initiative of the Weeds Research Division of the ARC-PHP. The SAPIA database now holds 96 000 georeferenced records of approximately 850 alien plant taxa growing outside of cultivation, and has provided crucial data on plant invasions for scientific studies.

Lesley served as the SAPIA coordinator from the outset, but following her retirement in March 2020, responsibility for SAPIA has been transferred to the South African National Biodiversity Institute (SANBI). Before she signed off, Lesley compiled this book as a follow-up to her previous one, *Alien Weeds and Invasive Plants*, published in 2001. The new book provides descriptions, distributions and illustrations of more than 400 species, and includes all listed invasive plant species that are covered by the Alien and Invasive Species Regulations of the National Environmental Management: Biodiversity Act (NEM:BA) (10/2004).

The book begins with a section on the impacts of invasive species, the various categories of invasive status – such as transformers, special effect weeds or emerging weeds – and control methods, but the bulk of the book is devoted to the identification of the species, presented in typical field-guide format. Each species account, with accompanying photos and maps, includes its legal and invasive status, biological control if available, region of origin, cultivated uses, habitats invaded, potential threats or impacts and other harmful properties. A quick guide to identification is provided inside the back cover for the major groups of plants.

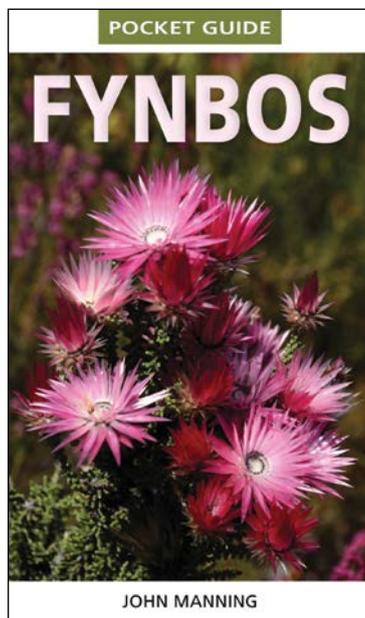


The book costs R230, excluding courier cost. To order a copy, contact Hendrieta Moletsane at [MoletsaneH@arc.agric.za](mailto:MoletsaneH@arc.agric.za).

# Books

## Pocket Guide to Fynbos

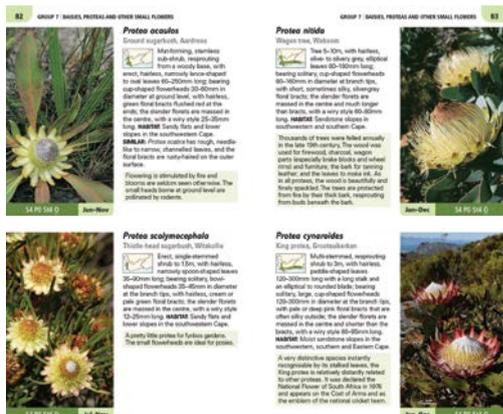
By John Manning. Struik Nature.



John Manning is the author of several wildflower guides, including the *Field Guide to Fynbos*, first published in 2007 and updated in 2018. This is a much more compact booklet, easier to slip into a shirt pocket or backpack to take along on hikes. Despite its small size, it still covers more than 300 species of fynbos plants, focusing on the most striking and commonly seen examples, which makes it a good option for novice flower-spotters or visitors to the Cape.

Each species entry includes concise descriptions of the plant and its habitat, a distribution map and photograph, and an indication of the flowering months, as well as a set of letters and numbers linked to a floral key on the inside front cover. The species are divided into 10 distinct groups for ease of use, and there is an introduction detailing the origins, diversity, adaptations and conservation of this unique flora. The recommended retail price of the book is R190, and it is available as an e-book too, at R119.

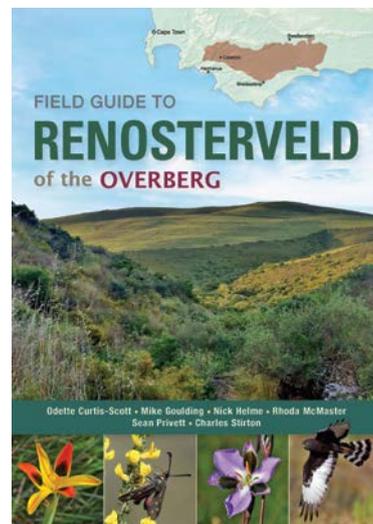
John Manning is a botanist based at the Kirstenbosch branch of the South African National Biodiversity Institute (SANBI), and a world authority on the iris and hyacinth families. In 2018, the Southern African Society for Systematic Biology (SASSB) gave him its Award for Extraordinary Contributions to Systematics in Southern Africa, in recognition of both his scientific endeavours and his initiatives to raise public awareness and the profile of the discipline.



## Field Guide to Renosterveld of the Overberg

By Odette Curtis-Scott, Mike Goulding, Nick Helme, Rhoda McMaster, Sean Privett and Charles Stirton. Struik Nature.

Five years in the making, this book has been a labour of love for lead author Dr Odette Curtis-Scott, founder and Director of the Overberg Renosterveld Conservation Trust. She has spent almost two decades conducting research, managing conservation projects and campaigning for the preservation of Renosterveld, one of the world's most threatened vegetation types. Part of the Fynbos biome, about 95% of the original extent has been lost to agriculture through planting of crops and overgrazing.



The book focuses specifically on the Renosterveld in the Overberg region of the Western Cape, and being the first of its kind, it will be a welcome addition to the bookshelves of the area's inhabitants. It's likely that farmers who have embraced the concept of conservation stewardship will be particularly interested, and the book includes a set of guidelines for good land-management practices. But all professional and amateur botanists will enjoy paging through the book and marvelling at the diversity of flowers, which often appear as small, hidden treasures amongst the rather drab Renosterveld shrubs.

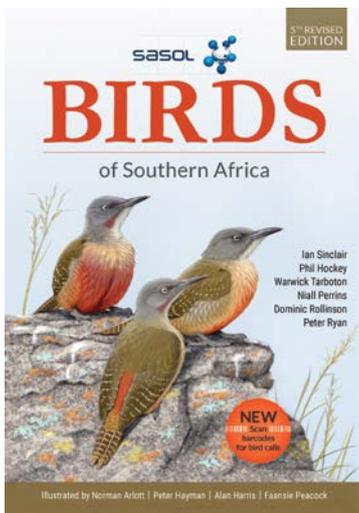
More than 980 plant species are featured in the book, but there's also a short section covering 140 animal species, from insects and reptiles to birds and mammals. An in-depth introduction sets the scene with a thorough overview of Renosterveld's conservation importance and ecology. The recommended retail price of the book is R420, but it is also available as an e-book for R290.





## Sasol Birds of Southern Africa

By Ian Sinclair, Phil Hockey, Warwick Tarboton, Niall Perrins, Dominic Rollinson & Peter Ryan. Struik Nature.



*Sasol Birds of Southern Africa* was first published in 1993, with Ian Sinclair as the sole author. Over the years, other ornithologists and birding experts have updated the book, and new illustrators have joined the team too. So this '5th revised edition' not only includes the latest species records, but revised text, maps and plate annotations, and over 800 new illustrations.



**STRUIK NATURE CALL APP**



Apple App Store

**DOWNLOAD FREE APP**  
to access the calls in this book by scanning a QR code or visiting the relevant app store.

See page 16 for further information on call app.



Google Play Store

The book is in the format of a typical field guide, and there is a choice of either a softcover version (R370) or a more rugged PVC one (R390). It is also available in Afrikaans.

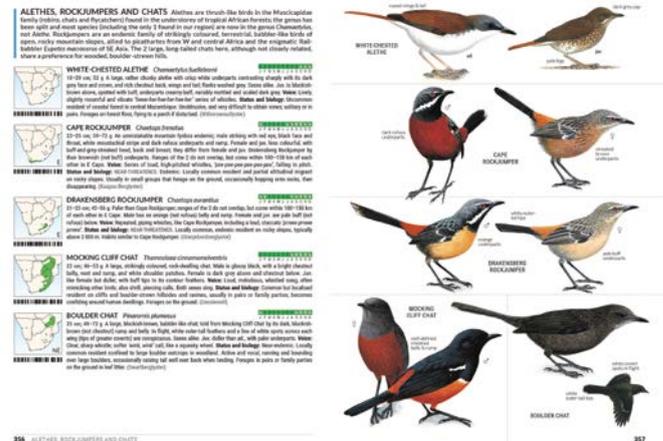
Then there's the larger-format version, *Sasol The Larger Illustrated Guide to Birds of Southern Africa*. This is more suitable for browsing at home, and is available as a softcover only, with a recommended retail price of R450.

What's more, with a smartphone in hand, it's now possible to listen to bird calls and songs for 866 of the species. All that's required is to download the free Struik Nature Call app from the Apple or Google Play store, and then scan the small barcode beneath the distribution map for the species. The app works well and is an added bonus to the book – it cannot be used on its own.



**GORGEOUS BUSHSHRIKE** *Telophorus viridis*

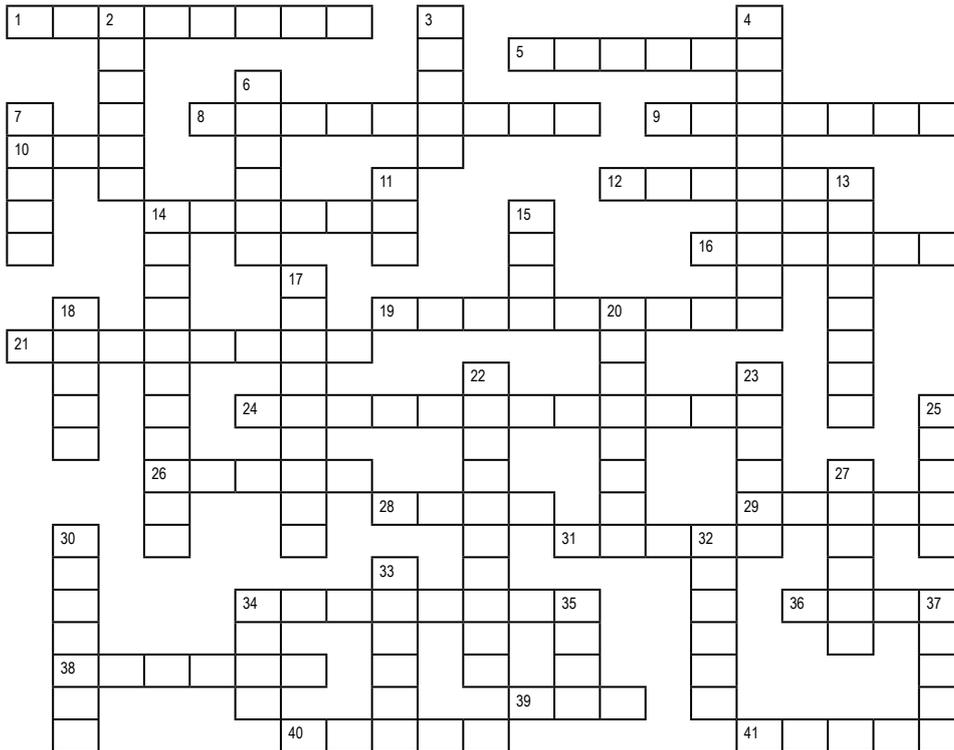
19 cm; 37 g A stunning, unmistakable, crimson-throated bushshrike. Male has black lores, a black line through eyes and black malar stripe joining broad, black breast band. Female lacks black facial pattern and has a narrow, black breast band and olive-green underparts. Juv. has dull yellow underparts, no breast band and a plain yellowish-green crown and face; breast band and red throat develop from 3 months. Olive-green head distinguishes it from juvs of other bushshrikes except juv. olive-morph Olive Bushshrike (from which it is inseparable in the field). **Voices:** Male song is a penetrating 2-5-syllabled 'kong-kon-kooi' or 'kong-kooi-kooi'; also rasping calls. **Status and biology:** Common resident in dense, tangled thickets, especially among low undergrowth on fringes of coastal and lowland forest. A skulking bird, more often heard than seen. (Konkolt)



Finally, for those who would rather access all the information on a smartphone or tablet, there's the updated *Sasol eBirds Southern Africa* app, also refreshed with all the updates of the 5th edition. While the books contain only illustrations, the app has photographs too – more than 2 700 of them. Plus the bird calls are included as part of the species entry, where available, as well as on the alphabetic and taxonomic lists accessible from the menu. Users can select English or Afrikaans as their language choice, and set their location if desired. The Smart Search function allows the species entries to be searched on the basis of bill type, bird size, colour and habitat, which should make bird identification considerably quicker and easier. Users can also create separate 'life-lists' of the birds they've identified on different outings, and these can be searched and sorted by date or alphabetically. The app is available on Apple and Android app stores for R 379,99.

# Test your knowledge

All of the answers can be found in this issue of Quest



**ACROSS**

- 1 A kind of fridge that uses mixtures of two isotopes
- 5 A sample of living tissue taken for examination or culture
- 8 Otters and wolverines are grouped under this name
- 9 A storage facility for a collection of biological samples
- 10 The IUCN \_\_\_ List of Threatened Species
- 12 A gas used for extreme cooling and balloons
- 14 A temperature scale that starts at absolute zero
- 16 A single unit of light
- 19 Describes temperatures between -150°C and absolute zero
- 21 English common name for *Artemisia* or umhloniyane
- 24 A surveying instrument that uses radio waves to measure distances
- 26 An altimetry instrument on NASA's ice-monitoring satellite
- 28 \_\_\_-Einstein condensates are a fifth state of matter
- 29 A project taking place beneath a mountain in Italy
- 31 An experiment in the Southern Ocean
- 34 Slowly moving masses of ice
- 36 Acronym describing the vapours given off by solvents
- 38 The kind of virus that causes COVID-19
- 39 An oceanographic instrument that records temperature and other parameters
- 40 A kind of dish used for laboratory cultures
- 41 Cryogenic condensation relies on \_\_\_ change

**DOWN**

- 2 This 1.0 m telescope at SAAO's field station in Sutherland was installed in 2017
- 3 Shrimp-like crustaceans that support Antarctic food webs
- 4 Term for organisms living on the underside of rocks
- 6 The space telescope, sometimes called HST
- 7 The cryo\_\_\_ is a South African invention used in eye surgery
- 11 The nucleic acid that stores genetic instructions
- 13 A change in a DNA sequence
- 14 Africa's highest and coldest mountain peak
- 15 Acronym for the climate pattern caused by periodic variation in sea surface temperatures
- 17 The \_\_\_ Nebula is the coldest natural place in the universe
- 18 An app-based game used in the Mandela Day coding tournament
- 20 Describes the lowest temperature at which the liquid phase is present in a mixture
- 22 The term used for all the frozen parts of the planet
- 23 The solid form of carbon dioxide
- 25 Describes species introduced from outside their natural range
- 27 This research station in Antarctica holds a temperature record
- 30 This organisation focuses on seabird rehabilitation
- 32 The boiling point of \_\_\_ nitrogen is -196°C
- 33 NASA's ice monitoring satellite
- 34 The basic unit of biological inheritance, passed from parent to offspring
- 35 Largest telescope at the SAAO field station in Sutherland
- 37 Fossils of the \_\_\_tooth cat have been found at Langebaanweg

## BRAINTEASERS

Lethabo's mother was 27 when he was born. 8 years ago she was twice as old as Lethabo shall be in 5 years' time. How old is Lethabo now?

Mary's age this year is a multiple of 8. Next year it will be a multiple of 7. How old is Mary?

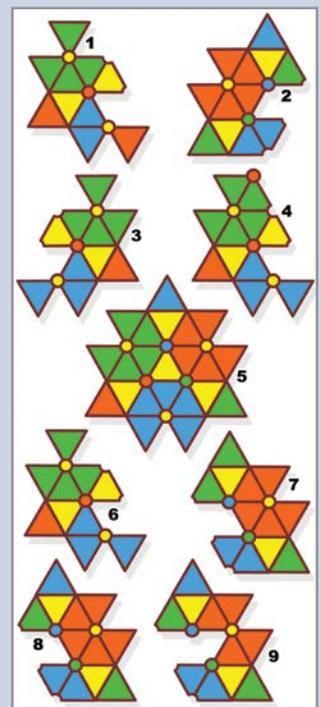
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**Answer to Maths Puzzle no. 53**

Place one white marble in one bowl, and place the rest of the marbles in the other bowl (49 whites and 50 blacks). This way you begin with a 50/50 chance of choosing the bowl with just one white marble, so your life is saved! But even if you choose the other bowl, you still have almost a 50/50 chance at picking one of the 49 white marbles.

## PICTURE PUZZLE

Which two pieces were used to produce the pattern 5?





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