SCIENCE FOR SOUTH AFRICA

Quest

VOLUME 13 | NUMBER 4 | 2017
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HUBBLE'S MESSIER CATALOGUE

Some of the best images from the Hubble Space Telescope

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Africa's largest eagle in free fall

SEAMESTER

SOUTH AFRICA'S UNIVERSITY AFLOAT

Quantum Walks
The importance of random motion

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WE TAKE A LOOK AT PLASTIC POLLUTION

ACADEMY OF SCIENCE OF SOUTH AFRICA

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SCIENCE ALL AROUND US

This final issue of Quest for 2017 takes us on a science trip around our world. Starting at sea, we take a look at how the new *SA Agulhas II* is contributing to educating postgraduate students and inspiring another generation of ocean scientists. The SEAmester programme takes students from across South Africa and offers a unique experience aboard this national facility. But the *SA Agulhas II* is not only there for educational programmes. Local and international scientists use this world-class facility to carry out research projects, one of which is examining exactly what happens to the literally tons of plastics that are produced each year. A frighteningly large amount of this plastic waste lands up in our seas, polluting the oceans and damaging marine life. The ocean itself is also the subject of much research, particularly in the face of climate change, warming seas and resultant changing ocean currents and scientists working from *SA Agulhas II* are making major contributions to our knowledge about these systems.

Quantum physics is the science of the incredibly small and understanding the physics behind the random motion of tiny particles is leading to advances in many fields, from an insight into the process of photosynthesis, to quantum computing.

And now to the unimaginably large and long ago – deep space and deep time. The Hubble Space Telescope has been quietly sending back images for some decades now and this issue of *Quest* features some of the more spectacular images – not just pretty pictures – but vital to our understanding of the evolution of the Universe and all that is present in it – literally looking back in time.

Science provides us with an explanation of the unknown, gives meaning to the world around us and offers a counter to myth and superstition. Enjoy your reading.

Bridget Farham
Editor – QUEST:
Science for South Africa

A plague of plastics

A sample of diverse plankton life from the bongo net occasionally includes a piece of micro plastic – the bright green shard in the background. *Morgan Trimble*

What happens to the tons of plastic we produce each year? Research during SEAmester 2017 gives us some idea and it isn't pretty. By Morgan Trimble with contributions from Katherine Hutchinson.

A crane hoists a small, buoyed net from the deck of the *SA Agulhas II* research vessel and lowers it to the ocean at starboard. The net bobs at the ocean surface as the ship slowly steams ahead. Seawater filters through the fine mesh, but the net captures anything bigger than a quarter of a millimeter. After fifteen minutes, the ship's crew hoist the net back on board. Vonica Perold, SEAmester 2017 lecturer and researcher working with Prof. Peter Ryan at the University of Cape Town, stands by to examine the catch. But this net isn't for fishing, it's for sampling plastics afloat at sea.

A GROWING PROBLEM

Humanity produces 300 million tons of plastic each year – that's 40 kg of plastic for each of the 7.4 billion people on Earth. Mass production of plastics took off in the 1940s and 50s, and society loved the material. Plastic is cheap, durable, and lightweight. But these very properties make plastic a disaster for the environment. In nature, plastic doesn't break down easily because of the chemical bonds that give plastic its strength.

The microbes that decompose your banana peels and newspapers won't touch plastic. Chucked out after a single use, everyday items like plastic bags and drink bottles will linger for hundreds

Students working on SEAmester II conduct an assignment on microplastics. The goal was to sample plastic in sand from Muizenberg beach. The students add water to the sand, stir vigorously, then allow the sample to settle. Plastic particles mixed in with the sand float to the surface of the water, where they can be collected and further analysed. *Morgan Trimble* to thousands of years. Today, besides the enormous annual production of new plastics, we're struggling with the mass of more than half a century of trash. The plastic problem is growing.

When the crew aboard the *SA Agulhas II* hoist the plastic-sampling net back on deck, Vonica takes the sample back to the ship's onboard lab for a preliminary look. Students and other scientists crowd around for a peek at the catch. They gasp in amazement and disgust. Here, in the middle of the South Atlantic Ocean, more than 1 000 km from Cape Town in a seemingly pristine ocean wilderness, a net dipped briefly in the surface waters has scooped up a palm full of plastic fragments.

PLASTIC AT SEA

Each year, 5 - 12 million tons of plastic enters the ocean. Some are bigger pieces – plastic sheets, buckets, buoys, and fishing equipment. Much is consumer waste – bottles, bags, takeout containers, straws – that finds a way into rivers and stormwater runoff and eventually flows to sea. A surprising amount comes from microscopic by-products of modern life – plastic microfibres that wash out of synthetic fabrics like fleece jackets and nylon athletic wear and the 'microbeads' that have become popular additives in cosmetics.

Plastic rubbish is, of course, an eyesore, but the problem is much more significant than aesthetics. At sea, plastic becomes an accidental snack for marine animals, from the tiniest plankton to the largest whales, and all the fish, turtles, seabirds, and marine mammals in between. Many mistake plastic for food – a floating bag looks like a tasty jellyfish to a sea turtle – but filter feeders who scoop up huge mouthfuls of seawater to collect miniature morsels of food can't avoid plastic bycatch.

Plastic kills marine animals in a variety of ways, from entanglement to clogged-up digestive tracts, but less visible and more terrifying is plastic's toxicity. Besides the potentially dangerous chemicals in the plastic itself, plastic in the sea acts like a magnet for other toxins, which can amplify in the food chain. Tiny fish eat plastic particles and absorb the toxins, bigger fish eat many tiny fish and absorb many toxins, even bigger fish eat those fish, absorbing even more toxins, and eventually, a fisherman might catch that big fish and serve it to his family.

In recent years, we've become aware of huge garbage patches at sea. The most famous is in the North Pacific, but given the dynamics of the ocean, garbage patches form in each of the large-scale swirling systems of currents called gyres. These gyres trap floating debris. These garbage patches are often described as plastic islands, but they're more like plastic soup. Under harsh conditions at sea, exposed to the sun and waves, bigger pieces of plastic become brittle and break up into smaller and smaller pieces. From satellite images or aerial flyovers or even from the deck of the *SA Agulhas II*, it's hard to see the full scale of the plastic problem.

SOLVING THE PLASTIC PROBLEM

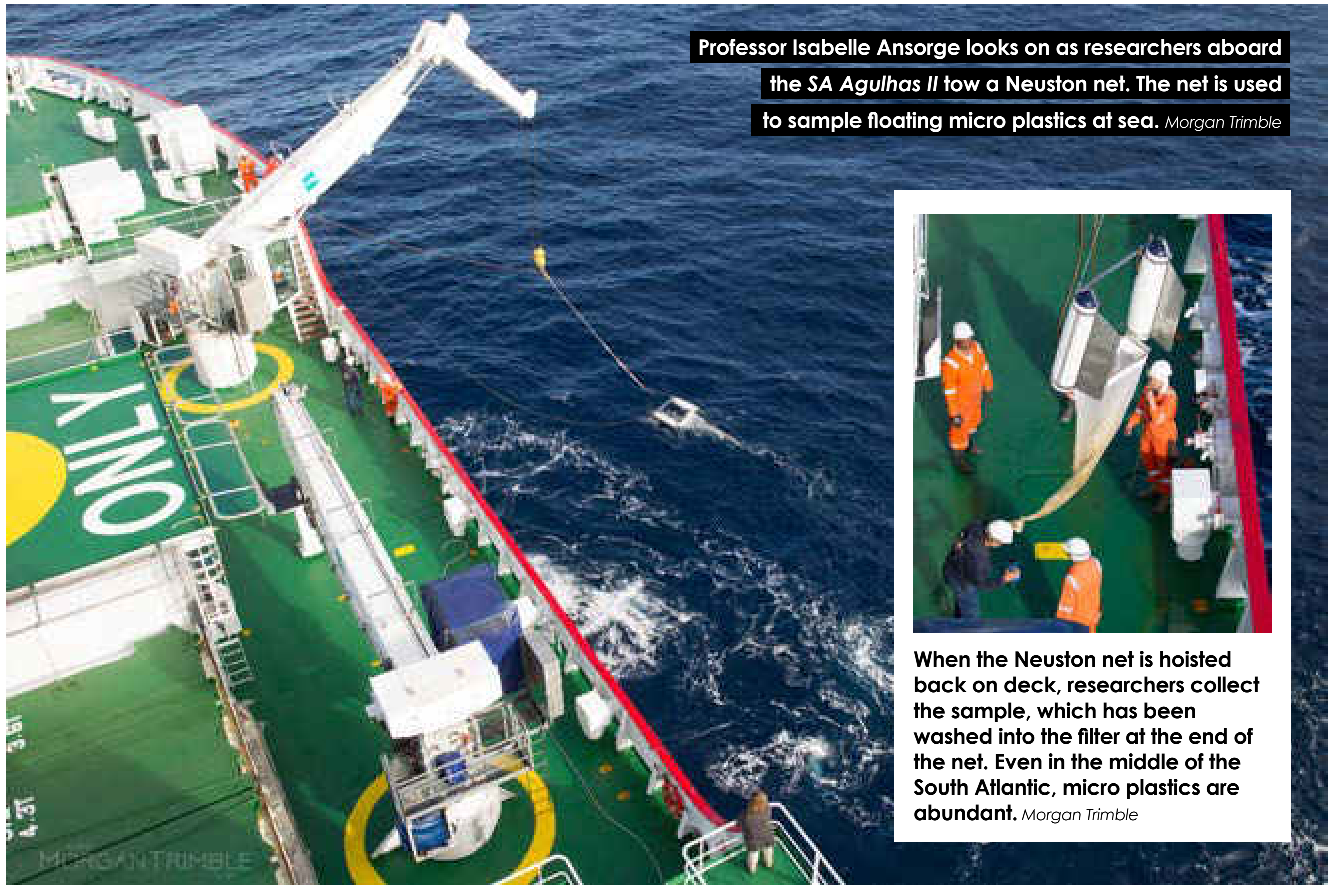
This is where the standardised sampling protocols like the net tows aboard the *SA Agulhas II* are important. As humanity grapples with the plastic problem, we still don't fully understand it. For example, although 5 - 12 million tonnes of plastic waste ends up in the sea each year, studies from around the world (similar to the plastic sampling done on board the *SA Agulhas II*) suggest that only 250 000 tonnes of plastic is floating on the ocean surface. Where is the rest? Floating somewhere below the surface? On the sea floor? In organisms? Only further research will tell.

In the meantime, all who witnessed the disturbing amount of plastic pulled from the middle of nowhere in the South Atlantic were inspired to think about solutions to the plastic plague (and hopefully everyone who reads this article will be too). While the global-scale problem is mindboggling, on a personal level, there are many ways to help.

South Africa ranks 11th worst among 192 coastal nations for mismanaged plastic waste, which might end up in the ocean. Once plastic at sea breaks into tiny fragments, it becomes impossible to clean up, so the solution is to prevent plastic from getting there in the first place. We need to use less plastic and dispose of it responsibly. How can you help? Avoid products with microbeads. Reject single-use plastics like straws, plastic bags, and unnecessary packaging. Buy in bulk instead of individually wrapped portions. Chose reusable products wherever possible – think reusable mugs, drink bottles, and shopping bags. Dispose of rubbish appropriately. Recycle. Join a clean-up effort in your neighbourhood or at your local beach, and pick up litter before it washes or blows into the ocean. Finally, tell a friend; help spread the word.

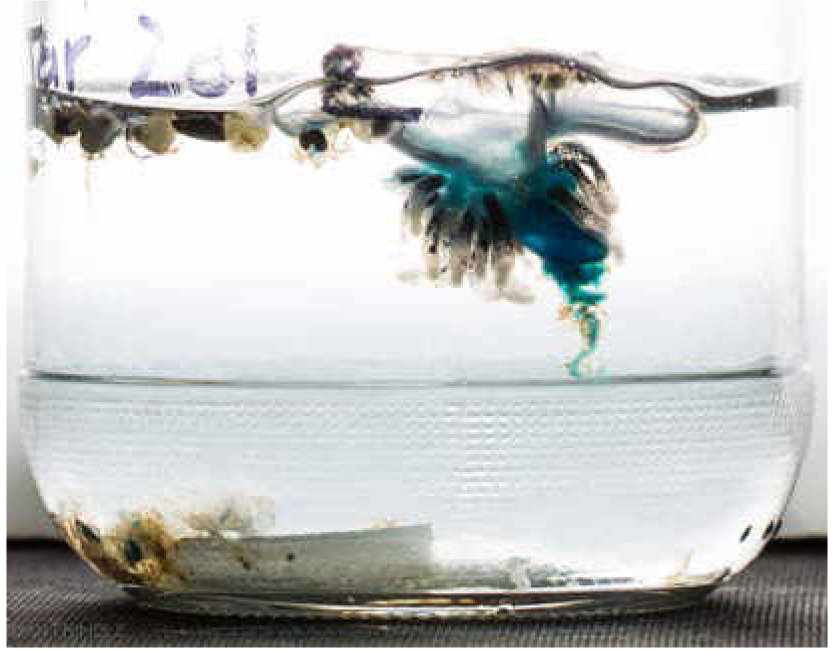
SEAmester is funded by the Department of Science and Technology. The Department of Environmental Affairs provides access to the *SA Agulhas II.*

Dr Morgan Trimble is an ecologist and science writer and lectured scientific communication aboard this year's SEAmester voyage. Katherine Hutchinson, PhD student at UCT affiliated with the South African Environmental Observations Network (SAEON), helped report this article and lectured ocean dynamics on SEAmester.



Professor Isabelle Ansorge looks on as researchers aboard the *SA Agulhas II* tow a Neuston net. The net is used to sample floating micro plastics at sea. *Morgan Trimble*

When the Neuston net is hoisted back on deck, researchers collect the sample, which has been washed into the filter at the end of the net. Even in the middle of the South Atlantic, micro plastics are abundant. *Morgan Trimble*



A sample from the Neuston net tow includes organic life like a bluebottle, but also microplastics. The plastic beads floating to the left of the bluebottle are known as mermaid's tears or nurdles – factories melt them to cast plastic products, but some spill into the sea during shipping or improper handling. *Morgan Trimble*

UCT researcher Vonica Perold pulls a bucket full of seawater to the deck of the *SA Agulhas II*. She later filters the sample to look for microfibers—tiny plastic threads that wash out of synthetic textiles and end up in the sea. *Morgan Trimble*

LANGUAGE TRANSLATION

A plague of plastics - inkinga kaplastiki

The microbes that decompose your banana peels and newspapers won't touch plastic. Chucked out after a single use, everyday items like plastic bags and drink bottles will linger for hundreds to thousands of years. Today, besides the enormous annual production of new plastics, we're struggling with the mass of more than half a century of trash. The plastic problem is growing – every year, 5 to 12 million tons of plastic enters the oceans. While the global-scale problem is mindboggling, on a personal level, there are many ways that you can help.

► Amagciwane enza ukuthi amakhasi kabhanana nephephandaba kubole, kodwa angeke kuwubolise uplastiki,uma usulahliwe emva kokusetshenziswa kanye nje. Izinto zikaplastiki ezifana nezikhwama nomabhodlela okuphuza zizohlala zingashabalali emva kokulahlwa iminyaka engaba izinkulugwane. kulezinsiku, ngaphandle kokukhiqizwa kwamaplastiki amasha amaningi,sibhekene nenkinga yemfucuza yeminyaka engaphezuldlwana kweminyaka engamashumi amahlanu. Inkinga kaplastiki iyakhula njalo ngonyaka, amathani angamamillion amahlanu (5) kuya kwayishumi nambili (12) kaplastiki angena olwandle. Kuyawuhlukumeza umqondo ukucabanga ngobukhulu balenkinga umhlaba wonke. Umuntu ngamunye zikhona izindlela angazisebenzisa ukusiza ukuxazulula lenkinga.

CURRICULUM CORNER

GEOGRAPHY GRADE 7
Natural resources and conservation

LIFE SCIENCES GRADE 10-12
Human impact and the environment

SEAMESTER SOUTH AFRICA'S UNIVERSITY AFLOAT

Now in its second year, the SEAmester postgraduate education programme inspires another generation of ocean scientists. By Morgan Trimble with contributions from Katherine Hutchinson.

Students look out over Cape Town from the helicopter deck of the *SA Agulhas II* as it departs for SEAmester II. *Morgan Trimble*

A turn of the microscope's focus knob snaps the backlit picture into clarity. Dancing and shimmying through drops of seawater, an unexplored world springs to life. Many of the organisms are completely transparent, but occasional flashes of orange, turquoise, and pink draw attention to the gaudier individuals. Some keep still, trying to evade detection as predators of the plankton world hunt their prey under my gaze. It's a galaxy in a petri dish.

The ocean's universe of creatures is an alien world to the SEAmester students and me, but it's familiar territory for Dr Paula Pattrick and Dr Eleonora Puccinelli, lecturers aboard SEAmester. Exotic names roll off the marine biologists' tongues and land in enthusiastic student ears. Pattrick and Puccinelli point out isopods, salps, copepods, amphipods, pteropods, forams and more. We find miniature versions of familiar creatures, the larval stages of squids, eels, fish, crabs, and lobsters. I can't believe the diversity of life hiding in a sample of sea water.

What we're looking at is plankton—the collective group of organisms that float in sea water, drifting with the currents with little ability to choose their course. In both description and diversity, this little bowl of plankton is a good analogy for SEAmester, a gathering of students and lecturers from incredibly diverse backgrounds and disciplines brought together aboard the *SA Agulhas II* research vessel. For 11 days, we go with the flow, bound to the ship's trajectory, with the singular goal of learning as much as possible about our oceans.

Students working on SEAmester II scan the horizon for whales. Finn, humpback and sei whales were among the marine mammals spotted during the cruise. *Morgan Trimble*

Students look out over Cape Town from the deck of the *SA Agulhas II* as it departs for SEAmester II. *Morgan Trimble*

THE SEAMESTER PROGRAMME

This year marks the second annual SEAmester cruise, building on the inaugural 2016 voyage's success. SEAmester is the brainchild of Prof. Isabelle Ansorge, Head of the Oceanography Department at the University of Cape Town.

'SEAmester was something I first thought about four years ago,' says Prof. Ansorge, explaining that while students at the University of Cape Town (UCT) tend to get opportunities to go to sea aboard the *SA Agulhas II* through various research programmes, students at other institutions are often not so lucky. 'There are plenty of students studying oceans or earth sciences, whether they're in Pretoria or Bloemfontein or KwaZulu-Natal, that have no chance to go to sea, particularly on this vessel, unless they're attached to the South African National Antarctic Programme. But the *SA Agulhas II* is a national facility. It's world class. It's probably one of the best research vessels in the world.'

Prof. Ansorge's solution was to create SEAmester as an educational programme for postgraduate students. The idea was to combine the programme with research cruises that the *SA Agulhas II* would be undertaking anyway. While a given oceanographic cruise might involve just 20 scientists, the ship has space for about 100 passengers. Prof. Ansorge saw those extra berths as an opportunity to provide first-hand experience at sea for students eager to learn.

'We put out an open call to all the postgraduate students at all the universities to apply for SEAmester,' explains Prof. Ansorge. 'We're providing access to this research vessel and the research we do to previously disadvantaged universities, to universities and technical institutes that have no traditional connection to the Southern Ocean, that have no traditional connection to the *SA Agulhas II*.' Without SEAmester, it would be challenging for these students to get experience on the ship. SEAmester requires a great deal of logistical and scientific planning, and for this Tahlia Henry, a former Cape Peninsula University of Technology (CPUT) student and current UCT/Nelson Mandela Metropolitan University (NMU) MSc student, is the lead coordinator.

The educational programme on SEAmester is intense. Students from diverse backgrounds join a comprehensive lecture programme, complete with practical components and mini research projects. All students enjoy learning the basics of oceanography and ocean dynamics, but they choose one of two focus areas: Oceans in a Changing Climate or Tools of the Trade. The former centres on marine biology, nutrient cycles, and human impacts on the oceans while the latter focuses on physical oceanography, the equipment and techniques oceanographers use and the instrumentation aboard the ship.

SEAmester also features more relaxed evening lectures about general-interest topics. Aboard this year's cruise, Prof. Pierre Cilliers from the South African

Students pose for a photo while on an engine tour of the *SA Agulhas II* where state-of-the-art equipment keeps the amazing ship on course. *Morgan Trimble*

Professor Ken Findlay explains distance sampling, a technique to estimate abundance of marine mammals like whales and dolphins. *Morgan Trimble*

National Space Agency lectured on the aurora phenomenon and the effect of space weather, like solar flares, on our technology. I presented tips for communicating science. Dr Greg Hofmeyr from the Port Elizabeth Museum and Prof. David Walker, lecturer at CPUT, spoke about their experiences in the South African Antarctic research programme. Prof. Ken Findlay of CPUT explained our ocean economy. Several students also took the opportunity to share their own projects from their home institutions.

RESEARCH AT SEA

Because SEAmester takes place during a research cruise, students also get to learn about, and help with, the research programme on board. In 2016, the SEAmester cruise coincided with a trip to the ocean region of offshore Port Elizabeth to service the Agulhas System Current Array (ASCA) that measures the speed and direction of the Agulhas Current. The array consists of a series of moorings – instruments strung along a line extending up through the water column from an anchor at the sea floor.

This year, we sail west out of Cape Town to the Prime Meridian at 0° of longitude to service a set of instruments that measure currents and temperature in the South Atlantic. This collection of instruments is called SAMBA, the South Atlantic Meridional Overturning Circulation Basin-wide Array. Its purpose is to monitor changes in the important ocean conveyor belt that regulates our climate.

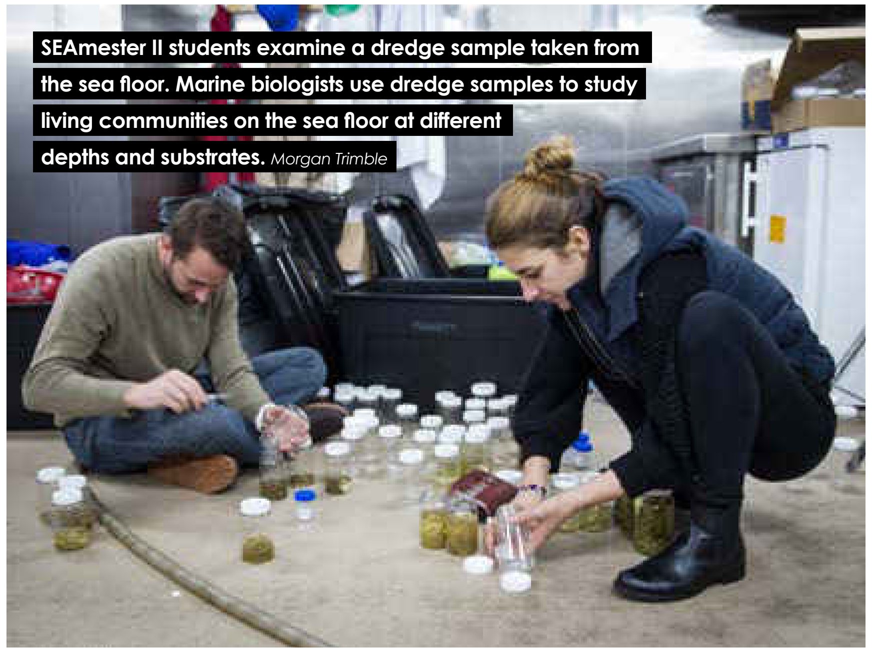
In addition to the work on the SAMBA array and traditional oceanographic profiling, SEAmester lecturers and scientists conduct research on a wide variety of topics including microbiology, plastic pollution, meteorology, plankton communities, nutrient levels, and atmospheric particles. Marine mammal and bird observers joined SEAmester to record sightings of whales and dolphins, and oceanic birds such as albatrosses, petrels, and shearwaters. Given the expense of surveying at sea and the threats to ocean wildlife, all research cruises are an opportunity to collect invaluable data. With the quantity and diversity of research work going on around the clock, SEAmester students never have a dull moment.

THE *SA AGULHAS II*

SEAmester lecturer Prof. Rosemary Dorrington from Rhodes University surveyed the microbial communities of the South Atlantic during the 2017 cruise. Her thoughts on the research vessel mirror many of the other scientists' opinions: 'The SA *Agulhas* II is the most awesome, cutting-edge research vessel on the planet. It's a huge privilege to be on the ship. She's got fantastic research laboratories, a crew that are specialised – the best trained for what they do, and a captain that is here to support the research. It's no wonder we're doing world-class research.'

The five-year-old *SA Agulhas II's* research facilities are excellent, but so too is the rest of the ship. Passengers sleep in comfortable cabins and enjoy access to a gym, sauna, library, business centre, dining hall, lounges, table tennis, and plenty of deck space to appreciate the ocean views. The ship is a research laboratory and a hotel rolled into one. From top to bottom, the ship is equivalent in height to a 15-storey building, and it's longer than a rugby field.

Early in the cruise, Prof. Ansorge explains to the students that being confined to the ship is one of the greatest benefits of SEAmester. Students have full access to the scientists and lecturers on board to get to know them in a friendly environment, network, ask advice on their current projects and future studies, and potentially even connect with a future supervisor or collaborator.



SEAmester II students examine a dredge sample taken from the sea floor. Marine biologists use dredge samples to study living communities on the sea floor at different depths and substrates. *Morgan Trimble*

A student examines a type of hermit crab found in a dredge sample from the sea floor. *Morgan Trimble*

A planktonic creature seen under magnification. Marine biologists used bongo net tows to sample plankton near the ocean surface. *Morgan Trimble*

While still above the continental shelf, Cape fur seals were a frequent sighting alongside the *SA Agulhas II*. *Morgan Trimble*

WHY STUDY OUR OCEANS?

Peering through the microscope at the life squeezed inside a single drop of seawater is awe-inspiring. But discovery for discovery's sake is not the only reason to study our oceans. Each of us, even those who have never been to the sea, depends on the oceans every day.

The oceans cover two-thirds of the planet, and they control our climate and weather. They absorb most of the energy from the sunlight that hits Earth. Oceans are by far our biggest storage space for carbon. The ocean's own version of oxygen-creating forests – photosynthesising phytoplankton – produce half of the oxygen we breathe. Furthermore, nearly a fifth of the animal protein humans eat comes from the sea.

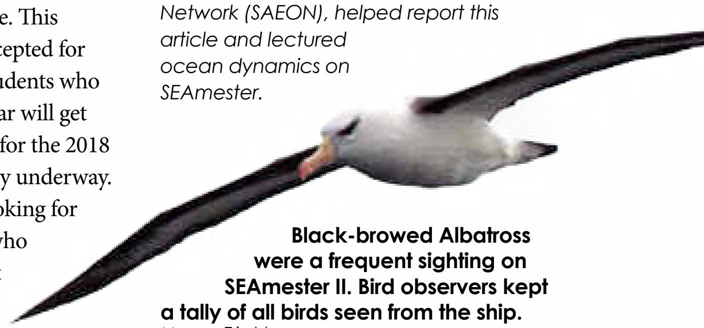
With South Africa's extensive coastline, our oceans also provide important economic opportunities, from fisheries to shipping to tourism. One of the three projects in the government's programme to fast-track their national development plan, Operation Phakisa (which means 'hurry up' in Sesotho), focuses on the ocean's economy. It seeks to create 1 million jobs and contribute R177 billion to the gross domestic product by 2033. Such rapid development calls for a new generation of ocean scientists to keep track of the health of the system and the sustainable use of its resources. SEAmester aims to fill this gap by inspiring young researchers to pursue careers in marine science.

Marc de Vos, who was on board the 2017 cruise to lecture meteorology and perform observations for the South African Weather Services, says, 'Natural sciences have such an impact on people's lives worldwide, yet they're not always front of mind when people think about what to study. SEAmester provides a condensed look into the world of natural science as it happens day to day. To have so many professionals from so many broad avenues of natural science, in one place at one time, all doing their thing for the students and teaching them around the clock is really special.'

The selection process for SEAmester students is highly competitive. This year, just one student was accepted for every six that applied. But students who were unable to attend this year will get another opportunity – plans for the 2018 SEAmester voyage are already underway. Prof. Ansorge says, 'We're looking for quality, motivated students who want to learn everything that is available on board. The students who attended the past two SEAmester courses can be proud of themselves to have been selected.'

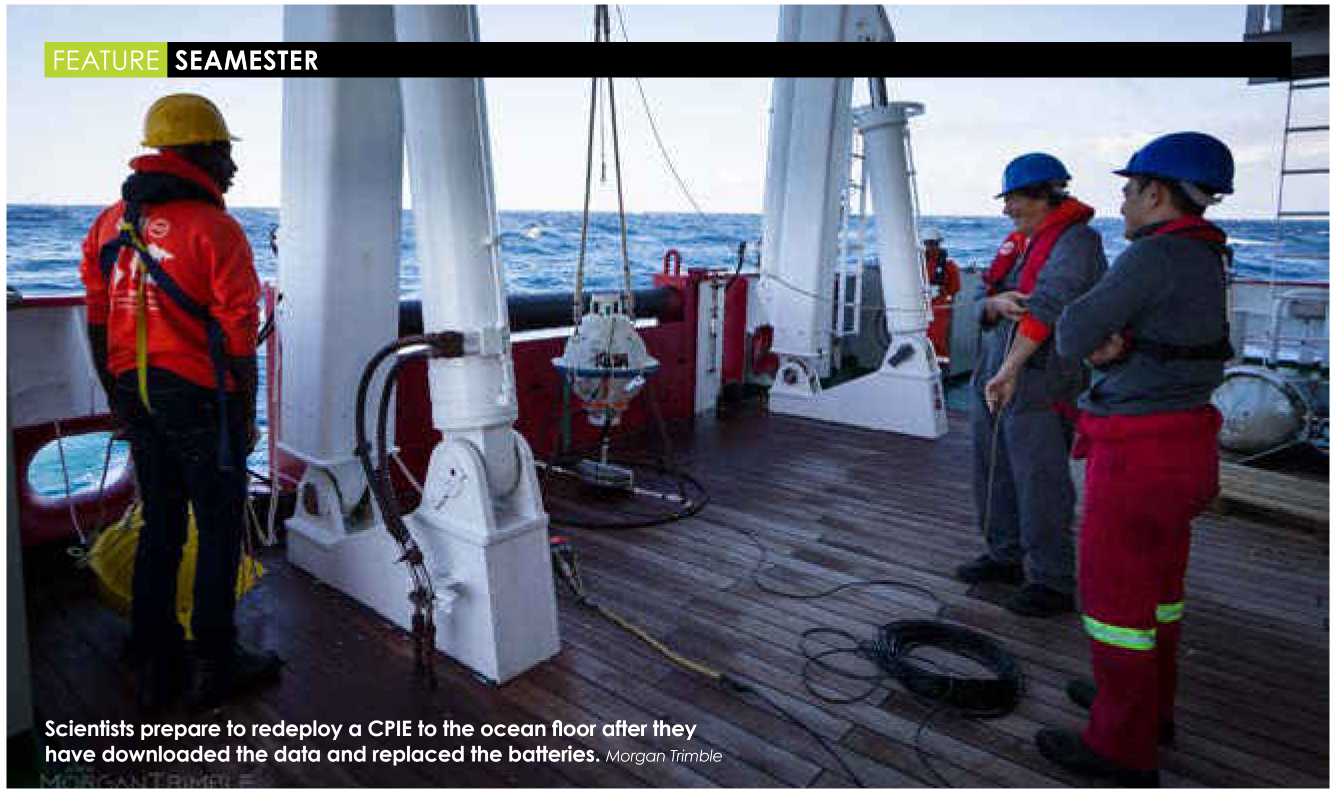
SEAmester is funded by the Department of Science and Technology. The Department of Environmental Affairs provides access to the *SA Agulhas II*.

Dr Morgan Trimble is an ecologist and science writer and lectured scientific communication aboard this year's SEAmester voyage. Katherine Hutchinson, a PhD student at UCT affiliated with the South African Environmental Observations Network (SAEON), helped report this article and lectured ocean dynamics on SEAmester.



Black-browed Albatross were a frequent sighting on SEAmester II. Bird observers kept a tally of all birds seen from the ship. *Morgan Trimble*

UCT post-doc Eleonora Puccinelli leads SEAmester students in sorting and cataloging dredge samples taken on a previous SA Agulhas II research voyage to Marion Island. *Morgan Trimble*



Scientists prepare to redeploy a CPIE to the ocean floor after they have downloaded the data and replaced the batteries. *Morgan Trimble*

SCIENCE AT SEA

From the air we breathe to the food we eat and the climate we experience, oceans play a major role in defining life on Earth. Here's a taste of what we learned during SEAmester 2017. By Morgan Trimble with contributions from Katherine Hutchinson.

DOING THE SAMBA FOR OCEAN DYNAMICS

If you could label a drop of water in the middle of the ocean and come back later to check on it, where would you find that drop in a week? A month? A year? A thousand years? The dynamics of water in the oceans are critical for controlling Earth's weather and climate and crucial to sea life. Understandably, oceanographers put a lot of effort into understanding ocean dynamics.

Intuitively, we know the oceans' surface waters aren't static. Throw a message in a bottle into the sea off the coast of South Africa, and there's a chance it will wash up on the shores of Brazil in less than a year (as proved by a student on SEAmester 2016, when a Brazilian man found and replied to a message she dispatched into the Agulhas Current). Ocean currents aren't limited to the surface layers. Deep water moves too. Ocean waters are constantly in motion, driven by the physics of energy reaching us from the sun and interrelated factors like wind, freshwater inputs from rain and rivers, gravity, and the influence of our spinning planet.

Researchers aboard the *SA Agulhas II* send an acoustic signal to release the ADCP from the sea floor. Once sighted, the ship's crew will hook and haul up the instrument so scientists can download the data and redeploy it. *Morgan Trimble*

The ADCP surfaces amid Cape fur seals and seabirds. *Morgan Trimble*

THE OCEAN CONVEYOR BELT

Although the physics is complicated, the notion is relatively simple – scientists use a giant conveyor belt as an analogy to visualise how water moves within and between our interconnected ocean basins.

Let's start in the North Atlantic. Here frigid, polar surface waters become extra salty because of the combined effect of wind-driven evaporation and the salt rejection that takes place as sea ice forms. This cold, saline water is dense, and thus heavy. It sinks rapidly, like a waterfall, to the bottom of the Atlantic. More sinking water pushes it from behind, so it flows along the sea floor southwards, towards Antarctica. When the water gets to the Southern Ocean, it meets the Antarctic Circumpolar Current, which carries it eastwards to the Indian and Pacific Ocean basins.

In these basins, the deep water slowly warms, becomes less dense and eventually rises upwards towards the sea surface. Surface water, in turn, needs to balance the huge volume of water sinking in the North Atlantic. So, surface water from the Indian Ocean moves southwest around South Africa – the famous Agulhas Current – and eventually heads north to the North Atlantic to start the cycle once more.

The Atlantic is the only basin that links the two poles. The shallow Bering Strait limits circulation between the Pacific Ocean and the Arctic, and the Asian land mass closes off the Indian basin in the north. Therefore, the north–south (meridional) exchange of water that takes place in the Atlantic is critical for global ocean circulation. This meridional overturning is of great interest to scientists.

MONITORING THE MERIDIONAL OVERTURNING CIRCULATION IN THE ATLANTIC

The ocean conveyor belt represents a delicate balance. Scientists are concerned that subtle changes in temperature or melting polar ice could disrupt ocean dynamics as we know them, with potentially disastrous consequences for life on land. Western Europe, for example, could freeze over without the influence of the warm tropical surface waters that flow towards the North Atlantic.

To monitor the Atlantic section of the meridional overturning circulation in detail, an international team of researchers have deployed two lines of instruments. In the north, scientists from the UK and USA installed sensors along the 26.5°N line of latitude and called it the RAPID array. In the south, South Africa is working with other nations to install and maintain a line of monitoring instruments at 34.5°S. This line is called SAMBA – South Atlantic Meridional Overturning Current Basin-wide Array.

These CPIEs – current-sensing pressure-equipped inverted echo-sounders — have been collecting data on current velocity and ocean temperature along the SAMBA line for four years. This information helps researchers understand how water moves in the Atlantic and whether climate change is affecting the process. Scientists aboard the *SA Agulhas II* collected the data and serviced the instruments, which they subsequently redeployed to the ocean floor. *Morgan Trimble*

SERVICING THE SAMBA LINE

The 2017 SEAmester voyage, an 11-day floating university for ocean sciences, coincided with a research cruise aboard the *SA Agulhas II* to service the instruments along the eastern section of the SAMBA line.

The eastern section consists of seven CPIES – current-sensing pressure-equipped inverted echo-sounders – moored to the sea floor. These capsules have multiple sensors to measure different physical aspects of the ocean. A current sensor measures current speed and direction just above the sea floor. A pressure sensor calculates how deep the ocean is. The inverted echo-sounder sends an acoustic signal up to the surface and waits for the echo that bounces off the interface between the surface of the ocean and the air. The time it takes for the echo to return is an indication of the average temperature of the water column, because sound moves faster through warmer water.

The array also features two bottom-moored ADCPs – acoustic Doppler current profilers. These instruments send sound signals too, but they measure both the time it takes for the echo to return, an indication of distance travelled, and the frequency shift of the echo, which indicates current speed and direction based on the Doppler effect. To measure current velocity at various depths, the ADCPs send 'pings' and listen for echoes that bounce off particles throughout the water column.

The CPIES and ADCPs of the eastern SAMBA line were installed in 2013, and ever since, they have been collecting

Thierry Terre, a research collaborator on SAMBA from Laboratoire de Physique des Océans, in France, joined SEAmester II to work with the instruments. *Morgan Trimble*

The *SA Agulhas II's* crew has successfully hauled in a CPIE that has been collecting data at the sea floor for four years. *Morgan Trimble*

Students aboard *SA Agulhas II* throw a message-in-a-bottle into the South Atlantic. This activity is a mini experiment to test surface currents. A student on SEAmester I was eventually contacted by a man in Brazil, who found her message-in-a-bottle nine months after she threw it into the Agulhas Current. *Morgan Trimble*

data, pinging the water column and recording its temperature and the velocities of its currents. The data are stored in the devices, patiently waiting for scientists to call the devices back to the surface and download this precious information. Our job on the SEAmester 2017 cruise was to do just this.

The first step in recovering an instrument is to navigate to its known coordinates. Then, to call the devices to the surface, scientists use a hydrophone – a specialised underwater speaker that transmits a unique code embedded in sound waves. When the CPIES and ADCPs hear their special instructions, they send an electric current through a wire attaching the main body of the instrument to its anchor, which holds it to the sea floor. The electric current moving through the wire exposed to salty seawater causes immediate corrosion. Within minutes, the wire breaks, releasing the instrument to float to the surface.

From the ship, observers spot the instrument, the crew uses a hook to catch and haul in the device, and the scientists set about excitedly downloading four years of data. Scientists then clean up and replace the batteries of the instruments before sending them back down to the sea floor to resume data-collection duties.

The value of the SAMBA line lies in the power of long-term observations to expose subtle environmental changes. Currently, researchers are measuring a baseline for the meridional overturning circulation and its natural variability so that they will be able to detect possible alterations in the future. The goal is to detect changes in the chemical and physical properties of the circulation and investigate how these changes are influenced by and in turn influence global climate.

SEAmester is funded by the Department of Science and Technology. The Department of Environmental Affairs provides access to the *SA Agulhas II.*

Dr Morgan Trimble is an ecologist and science writer and lectured scientific communication aboard this year's SEAmester voyage. Katherine Hutchinson, a PhD student at UCT affiliated with the South African Environmental Observations Network (SAEON), helped report this article and lectured ocean dynamics on SEAmester.

CURRICULUM CORNER

GEOGRAPHY GRADE 10-11
The world's oceans

LIFE SCIENCES GRADE 10-12
Human impact on the environment

LANGUAGE TRANSLATION

Science at Sea -ubuchwepheshe obusolwandle

Throw a message in a bottle into the sea off the coast of South Africa, and there's a chance it will wash up on the shores of Brazil in less than a year! The dynamics of water in the oceans are critical for controlling Earth's weather and climate and crucial to sea life. Lines of monitoring equipment moored to the sea bed are used to monitor everything about the ocean and how it changes.

► faka umlayezo ebhodleleni, uwufake olwandle olusogwini leningizimu ne afrika, kunamathuba okuthi lingagcina seliqhamuka ogwini lase Brazil kungakapheli unyaka! Ukushintsha kwamanzi olwandle kubalulekile ukulawula isimo sezulu ezweni,kanti futhi nakukho konke okuphila olwandle. Izintambo zemishini yokuqapha ezifakwe ngaphansi kolwandle sisetshenziswa ukubheka yonke into emayelana nolwandle nokushintsha kwalo.

QUANTUM WALKS

Bereneice Sephton, Angela Dudley and Andrew Forbes explain the importance of random motion.

Consider the path of tiny dust particles as they float in still air or the motion of those small specs of matter just visible in your glass of water. These are examples of random motion. It is an integral part of how the world operates and facilitates many of the fundamental processes that maintain the Earth, such as heat transport in materials and the transport of gases like oxygen, which are crucial to survival. It can even go so far as to describe the way animals forage and aspects of finances.

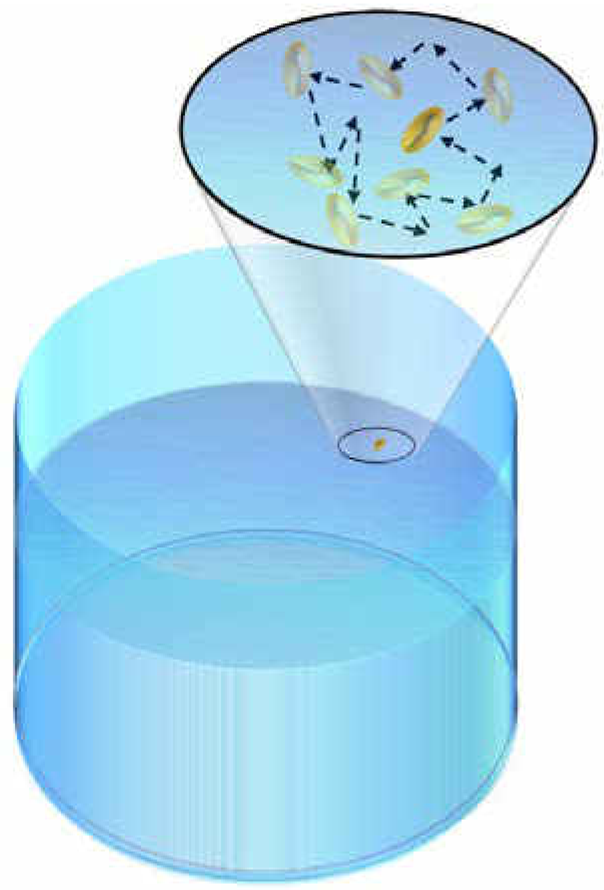


Figure 1. Robert Brown noted the stochastic, random movements of pollen floating on water, which resulted in the concept of random motion. The black arrows show the random path taken by the pollen grain where the overall path results in no net displacement.

RANDOM MOTION

So, what exactly is random motion? The answer can be dated back to 1827 when a botanist, Robert Brown, noted the movement of pollen floating on water (Fig. 1). He saw that the tiny bits of pollen moved in many random directions, but did not actually go anywhere – they had no overall displacement.

This tied in with the study of atoms and this movement was eventually shown to come from the random motion of fast-moving molecules that hit the pollen grains from all sides. However, different sides of the pollen experienced slightly greater forces than others, which resulted in the random movement of the pollen itself. Soon after this, in 1905, Einstein provided the mathematical foundation for this phenomenon, consolidating random motion as a foundation in many scientific studies today.

Understanding and being able to predict such motion lies in our ability to simulate it. However, how do you do this when the basic feature of something that is random is that there is no definable pattern and thus should not be predictable? The answer lies in the concept of the random walk.

RANDOM WALKS

Consider for a moment the idea of using the flip of a coin to make a decision. An example would be – shall I move left or right? To do this, you make each side of the coin indicate a direction, for example, heads to right and tails to left. By flipping the coin and moving in that direction, you are moving randomly. If you flip the coin again and move according to the outcome, another random movement is carried out. If you do this over and over again, you are creating random motion, or more specifically a random walk (see Figure 3(a) in Box 3). It follows that by assigning particular values to the available options and then randomly generating those assigned values, 'randomness' can be simulated by simply acting upon the randomly generated values. Associated outcomes can then be predicted.

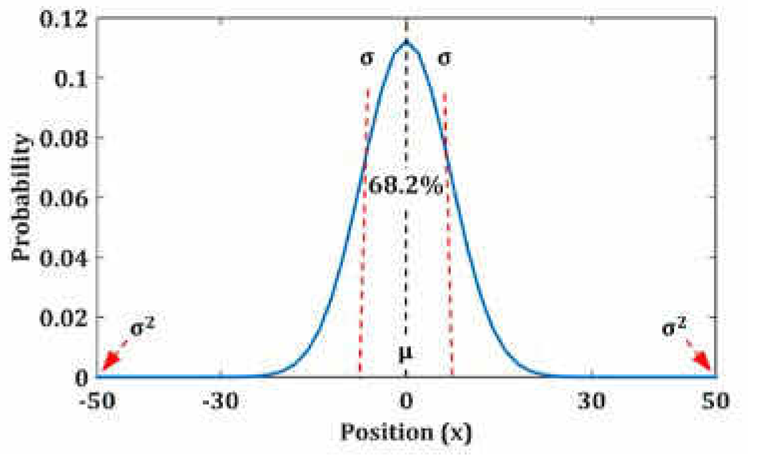
The result of such a simulation is a Gaussian distribution (see Box 1) where the most probable outcome, and thus the option that will happen most often, is found at the starting position. This is exactly what Robert Brown noted for the pollen.

Being able to predict random motion has allowed scientists

BOX 1: PROBABILITY DISTRIBUTION

This shows the Gaussian curve for a random walk with 50 steps taken. One standard deviation (σ) from the mean value (μ) for a data set describes the bounding value for which 68.2% of all the data points will be found (34.1% will be found on either side of the mean value).

A Gaussian probability distribution (type of bell curve) is a curve that shows the tendency of data to cluster about an average value, such as the grades of students in a class. How far most of the data spread across the possible values is measured through standard deviation. As standard deviation is calculated by taking the square root of the variance, this spread is often compared in terms of variance.



BOX 2: CLASSICAL AND QUANTUM WORLDS

The classical world, in physics, refers to the experiences around us every day – everything happening on a macroscopic scale. Here the rules of how everything works follow what can be expected: a ball hitting a wall will bounce back and you can only be in one place at a time. The quantum world is a little stranger. Here the rules are different and often opposite to what you would ordinarily expect. For example, the little transistors in your phone storing all your information in terms of 1s and 0s work by electrons 'tunnelling' through the bounding walls, i.e. the ball doesn't always bounce back. When you aren't looking, the question for particles isn't 'where is it?', but rather 'where isn't it?'.

These rules are for a much smaller scale though – the atomic scale. Consider the full stop at the end of this sentence. You would need to shrink it about 10^9 times to approximate the size of a carbon atom, so you cannot reasonably expect to walk through walls or get your shopping and ironing done at the same time.

Image of a transistor. *https://readtiger.com/wkp/en/History_of_computing_hardware*

to use the theory in modelling processes such as particle movements, how certain processes take place in your DNA and even in recommendations on who to follow on Twitter.

RANDOM SPREADING

The rate at which a probability distribution spreads (how wide the shape becomes) with the number of steps taken (coin flips) is of particular interest when characterising random walks, because this is related to how fast an answer (equivalent to a particular position) can be found in computing. Therefore, the variance (σ^2) is considered, which may be shown to vary linearly with the number of steps (n) taken in the characteristic random walk probability distribution: $\sigma^2 \propto n$

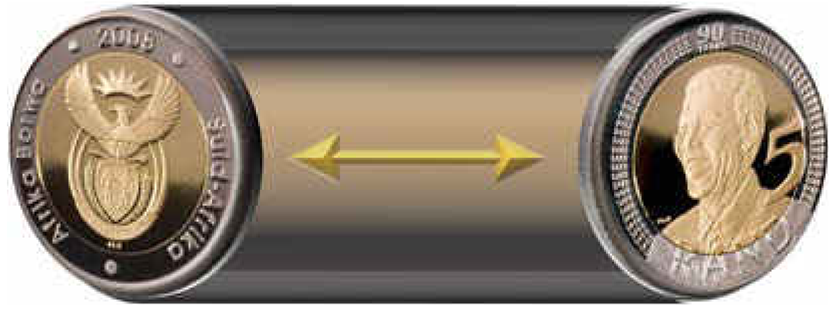
THE RECIPE FOR RANDOM

The recipe of a random walk may then be generalised into a walker (Bob), a random value generator (coin), a position space (road intersections), where the random values are assigned to particular directions and a propagator that moves the walker in the randomly generated direction (walking). By adding more directions (n) and another random value generator (e.g. dice) with a number of options that match the number of directions, Bob can go on an n-dimensional walk.

WALKING IN THE QUANTUM WORLD

The random walk has been largely successful in the world of classical physics, so what is the effect of taking the random walk to the world of quantum mechanics (see Box 2)? That is, what can be accomplished if the principle behind the working of the random walk is extended to work under the principles of the quantum world? To take the random walk into the quantum world, you have to use the phenomenon of quantum superposition. Superposition essentially says that something can occupy more than one position or property at the same time – put scientifically that 'something' can exist as a linear superposition of more

than one basis state. This means that the coin in the random walk can no longer be either heads or tails in the quantum equivalent, but is rather a superposition of heads and tails. In other words, the coin is simultaneously in the state of landing on heads *and* tails. We can describe this with the expression given in Figure 2. More specifically, complex probability amplitudes (see Box 3) are used – how much each property or position is favoured is determined by the relative value of the associated probability.



Coin = a [Heads] + b[Tails]

Figure 2. In the quantum world, the coin is in a state of being both heads and tails (superposition). 'How much' it is in either state is given as *a* for the heads state and *b* for the tails state.

BOX 3: PROBABILITY AND PROBABILITY AMPLITUDES

Probability in the classical world refers to the option of something occurring or, conversely, the frequency at which it will happen should you do it a certain number of times. It follows that there can be absolute certainty (100% = 1), no possibility (0% = 0) or something in between, such as 50% = 0.5. For example, in the random walk, the probabilities split at each intersection so 1 → 0.5 → 0.25 and when the intersections overlap, we add the contributing probabilities (see Fig 3(a)).

In the quantum world, the rules for probability, however, operate with a twist. The possibilities work in terms of what is known as complex probability amplitudes. Here you can add more of the same thing to another, but come out with absolutely nothing. To do this, complex numbers are used, which is simply saying $i=\sqrt{(-1)}$ so that $i^2=-1$ and a negative value is the result. We get back to the normal 'classical' probability by multiplying the amplitude conjugate product:

$P_{classical}=A^*A$

The amplitude is multiplied by itself with i made negative in the A* term. Basically, this means the trick is that complex probability amplitude in the quantum world can be negative, so when you add together some of the values, they can become less or cancel out. So if you add up the amplitudes before converting back to classical probability, the answers are completely different – for example, as in the case of a quantum walk, where the probability amplitude for every left turn (heads) has an i (see Figure 3(b)).

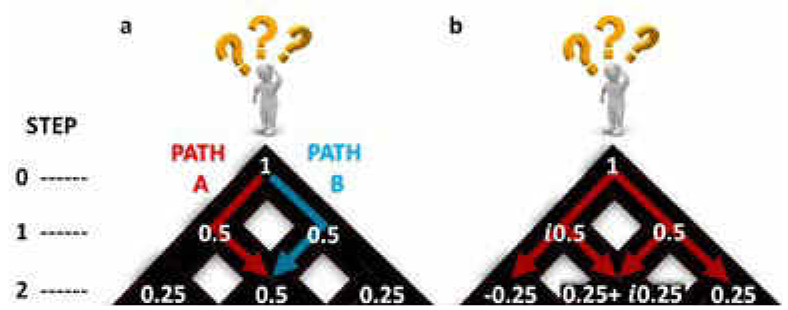


Figure 3: (a) Classical and (b) quantum probabilities for Bob's coin walk. Bob flips the coin to decide which intersection to take where tails indicates left and heads, right. Consecutive repetition of such decisions lead Bob on a random walk. The blue and red paths in (a) show two of the four possible routes Bob can take. Both end at the same position, making it the most probable (0.5). Conversely, for the quantum walk, Bob flipping a coin causes him to occupy and interfere with himself at all the possible positions at the same time.

To gain a crude impression of what is happening, you can think of this as causing the movement of the walker to both the right and left at the same time. In other words the walker, or Bob, is now in a superposition of occupying both positions +1 and -1 simultaneously (see Figure 3(b)). 'Flipping' the coin again results in a superposition of heads and tails for the walker at each of the +1 and -1 positions, causing Bob to move left and right again. An overlap in the states being simultaneously occupied then occurs, i.e. Bob at +1 moves to +2 and 0 while Bob also at -1 moves to -2 and 0 such that there are 'two movements' to 0. It follows that the position at 0 is more strongly favoured than that of ±2, resulting in constructive interference of the probabilities associated with these states. Bob will thus be more likely to be found at 0 when looking for him. Because these are probability amplitudes, the 'overlapping states' may also result in destructive interference. Subsequently, a reduced probability of finding Bob occurs at certain positions by simply adding more of quantum Bob. Bob is now interfering with himself: reinforcing and cancelling himself out over several positions at the same time. It is this interference that forms a significant difference between the classical random walk and quantum random walk.

QUANTUM SPREADING AND WEIRDNESS

Also, when we look at how fast quantum spreading can occur and thus how fast we can get our answer, the game of computing changes. In contrast to the classical case, where the variance has a linear limit, the quantum walk has a variance where: $\sigma^2 \propto n^2$

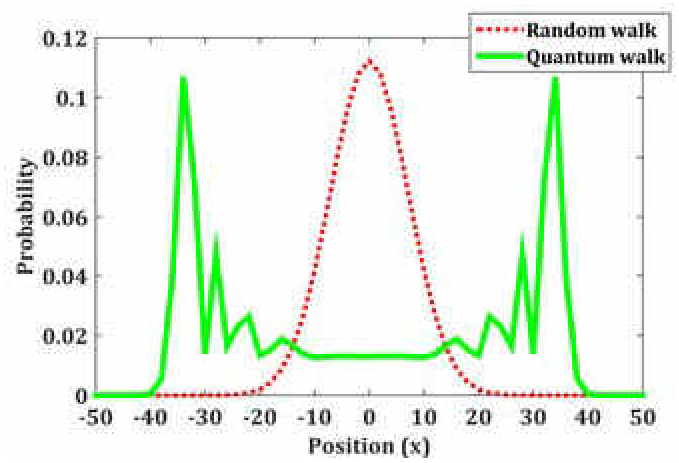


Figure 4: The quantum walk probability distribution (green line) is distinctly different to that of the Gaussian (dotted red line) occurring in the classical case where the destructive interference plays a large role. Here the probability of finding the walker is closest to the ends of the distribution, with minimal probability at the original position (position 0).

which means the answer/position can be found quadratically faster.

All this peculiarity takes the form of a largely surprising result, wrapping up the strangeness associated with these walks. If you follow the interference in a quantum walk, what you end up with is opposite to what you expect – almost an inverse of what we see for the classical case. Destructive interference occurs at the centre, which seems counter-intuitive to what you see in the random walk. In fact, the greatest probability of finding Bob is close to the ends of the distribution and the larger the number of steps taken, the smaller this probability in the middle becomes (see Fig. 4).

The quantum walk has fast become a field of great interest to scientists over the last 20 years as it holds the potential for unlocking many scientific and technological advances. Derived algorithms already show promise in classical computers. When physically implemented, though, the quantum walk can form the basis of quantum computers. Here the quadratic speedup will direct the next step in computing power. The potential to crack the bit-encryptions used for many security systems could become something done in days, rather than over an infinitely long time. Many complex mathematical problems will be easy to solve. Nature does its own quantum walk when plants photosynthesise, so generating our own quantum walk will help in understanding one of nature's energy transportation systems.

It is of little wonder that researchers are hard at work on making quantum walks come to life, using particles such as atoms, electrons, ions and photons to do the walking. Quantum systems are very sensitive though, so the race for the most number of steps taken is limited to just a few. A new approach has recently been explored where special properties of classical light make it possible to 'walk' laser beams instead. The associated reduction in sensitivity set a standing record of ~67 steps. Furthermore, the quantum walk challenge extends to making walks with more than one walker and higher dimensions. It follows then that quantum walks, strange as they are, promise an exciting future.

FURTHER READING

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Andrew Forbes is a Distinguished Professor within the School of Physics, University of the Witwatersrand, where he leads a group working on Structured Light (www.structuredlight.org). Dr Angela Dudley is a senior researcher at the CSIR and has an honorary appointment at the University of the Witwatersrand. She works on laser beam shaping and its applications. Bereneice Sephton is completing her Masters degree at the University of the Witwatersrand, on a studentship from the CSIR, with a focus on quantum walks.

LANGUAGE TRANSLATION

Quantum walks- ukuhamba okubalulekile/ okukhulu

Consider the path of tiny dust particles as they float in still air or the motion of those small specs of matter just visible in your glass of water. These are examples of random motion. It is an integral part of how the world operates and facilitates many of the fundamental processes that maintain the Earth, such as heat transport in materials and the transport of gases like oxygen, which are crucial to survival.

Cabanga umgudu wezinhlayiya ezincane zezintuli zindiza emoyeni, noma ukunyakaza kwalezozinhlayiya ezincane engilazini yakho manzi. Lokhu kuwumzekelo wokunyakaza okuzenzekelayo. Le, indlela umhlaba osebenza ngayo, futhi kwenze izinto ezibalulekile emhlabeni zenzeke ukuze umhlaba uhlale uyiwo. Njengokuhamba kokushisa okuhamba ngokuthintana kwezinto noma ukuhamba komoya esiwuphefumulayo, okubalulekile ukuthi kube nempilo.

CURRICULUM CORNER

PHYSICAL SCIENCES GRADE 10-11

Kinetic molecular theory- Brownian motion

MATHEMATICAL LITERACY GRADE 10-12

Probability

Hubble's Messier Catalogue

Although there are as many as 100 billion comets in the outer regions of the solar system, prior to 1995 only around 900 had ever been discovered. This is because most comets are too dim to be detected without the proper astronomical equipment. Occasionally, however, a comet will sweep past the sun that is bright enough to be seen during the daytime with the naked eye.

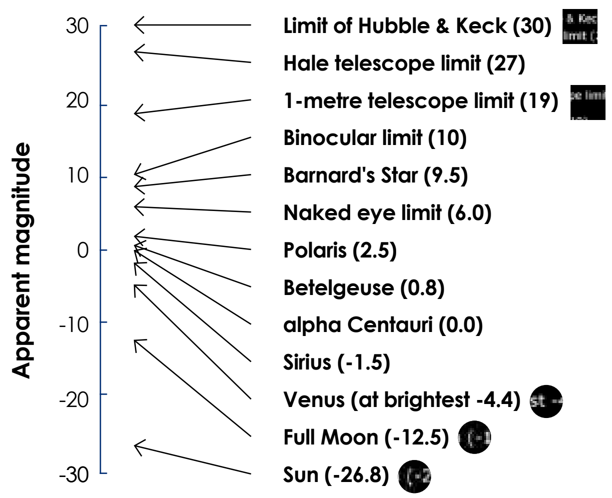
APPARENT AND ABSOLUTE MAGNITUDE

Some stars appear very bright but are actually fainter stars that lie closer to us. Similarly, we can see stars that appear to be faint, but are intrinsically very bright ones lying far away from Earth. The Greek astronomer Hipparchus was the first to categorise stars visible to the naked eye according to their brightness. Around 120 BC, he invented six different brightness classes, called magnitudes, where the brightest stars were magnitude 1 and the faintest were categorised as magnitude 6. Today, astronomers use a revised version of Hipparchus's magnitude scheme called 'apparent magnitudes', as well as 'absolute magnitudes' to compare different stars.

Apparent magnitude

The power radiated by a star is known as its luminosity. However, the apparent magnitude, m, is the power received by an observer on Earth. Since we now can see very faint stars using telescopes, the scale extends beyond the magnitude 6 that Hipparchus marked down as the faintest on his scale.

As you can see, the magnitude numbers are bigger for faint stars, and magnitudes are negative for very bright stars. Since the scale is logarithmic, a magnitude 1 star is 100 times brighter than a magnitude 6 star, i.e. the difference between each step on the scale is equal to a decrease in brightness of 2.512 and $(2.512)^5 = 100$.



Absolute magnitude

Comparing apparent magnitudes is a useful reference for astronomers, and these often appear next to stars on star maps. Apparent magnitude, however, does not tell us about the intrinsic properties of the star, so it is necessary to use the concept of absolute magnitude.

The absolute magnitude, M, of a star is defined as what the apparent magnitude of that star would be if it were placed exactly 10 parsecs away from the Sun. Most stars are much further away than this, so the absolute magnitude of stars is usually brighter than their apparent magnitudes.

To calculate the absolute magnitude for stars, we use the following equation:

$M = m - 5 \log (D/10)$

The value m-M is known as the distance modulus and can be used to determine the distance to an object, often using the following equivalent form of the equation:

$D = 10^{(m-M+5)/5}$

Star (Bayer)	Star (Proper)	Parallax (arcseconds) (arcseconds)	Apparent mag. (m)	Absolute mag. (M)
α Canis Majoris	Sirius	0.37921	-1.44	1.45
α Carinae	Canopus	0.01043	-0.62	-5.53
α Boötis	Arcturus	0.08885	-0.05	-0.31
α1 Cenaturi	Rigel Kent	0.74212	-0.01	4.34
α Lyrae	Vega	0.12893	0.03	0.58
α Aurigae	Capella	0.07729	0.08	-0.48
β Orionis	Rigel	0.00422	0.18	-6.69
α Canis Minoris	Procyon	0.28593	0.40	2.68
α Orionis	Betelgeuse	0.00763	0.45	-5.14
α Eriadani	Achernar	0.02268	0.45	-2.77

Apparent and Absolute Magnitudes for the ten brightest stars on the night sky.

Charles Messier (1730–1817) was a French astronomer best known for his "Catalogue of Nebulae and Star Clusters." An avid comet-hunter, Messier compiled a catalogue of deep-sky objects in order to help prevent other comet enthusiasts from wasting their time studying objects that were not comets. *R. Stoyan et al., Atlas of the Messier Objects: Highlights of the Deep Sky (Cambridge University Press, 2008)*

The Hubble Space Telescope is equipped to take images in various wavelengths of light in order to provide more insight into its targets. The famous Pillars of Creation in the Eagle Nebula (also known as M16: the 16th object in Charles Messier's catalogue) were imaged using both visible (left) and infrared (right) filters. Using infrared light, Hubble is able to probe past the dense gas and dust of the nebula to reveal stars that are hidden in visible wavelengths.
Credits: NASA, ESA/Hubble and the Hubble Heritage Team

One such instance occurred in 1744. Comet Klinkenberg-Chéseaux, discovered by three amateur astronomers in late 1743, grew steadily brighter as it approached the sun. By the end of February 1744, the comet had reached its peak brightness at an apparent magnitude of –7, making it the brightest object in the sky except for the sun and moon. The comet's brilliance captured the interest of professional and amateur astronomers alike, including a young Charles Messier.

Born in 1730 in Badonviller, France, Messier had to give up formal education at age 11 when his father died. Soon after, he witnessed the spectacular Comet Klinkenberg-Chéseaux, which ignited his passion for astronomy. At the age of 21, Messier was hired as a draftsman for the French navy. He learned to use astronomical tools and became a skilled observer. For his efforts, Messier was eventually promoted to the chief astronomer of the Marine Observatory in Paris, where he pursued his interest in comets. He discovered over a dozen comets, earning him the nickname 'Comet Ferret' from King Louis XV. In 1758, Messier was in the process of observing one such comet when he was distracted by a cloudy object in the constellation Taurus. Upon further observation, he realised that the object could not be a comet because it was not moving across the sky. In an effort to prevent other astronomers from mistaking the object for a comet, Messier took note of it and began to catalogue other comet-like 'objects to avoid'. This comet-like object that Messier observed was NGC 1952. Commonly known today as M1 (Messier 1) or the Crab Nebula, it is the first object in Messier's *Catalogue of Nebulae and Star Clusters*. By the time of his death in 1817, Messier had compiled a list of 103 objects in the night sky using his own observations with various telescopes and the discoveries of other astronomers. The catalogue was revised in the 20th century and now contains 110 objects.

The Messier catalogue includes some of the most fascinating astronomical objects that can be observed from Earth's Northern Hemisphere. Among them are deep-sky objects that can be viewed in stunning detail using larger telescopes but are also bright enough to be seen through a small telescope. This characteristic makes Messier objects extremely popular targets for amateur astronomers possessing all levels of experience and equipment. They are so popular, in fact, that they have inspired a special award from the Astronomical League (an organisation for amateur astronomers) given to observers who are able to spot each of these objects. Those who succeed receive a certificate and are given the distinction of being in the Messier Club.
While the Hubble Space Telescope has not produced images of every object in the Messier catalogue, it has observed 93 of them as of August 2017. Some of Hubble's photographs offer views of a given object in its entirety, but many focus on specific areas of interest. While Hubble is able to magnify objects very effectively, it has a relatively small field of view. This means that, in some cases, Hubble would need to take many exposures to capture an entire object.

Although this is not always an efficient use of its time, as is the case for the widely spaced 'open' star clusters in the Messier catalogue, many exposures are taken when the scientific value justifies the time spent. One of these objects is the Andromeda galaxy (designated M31 in Messier's catalogue). In order to create a mosaic image that depicts almost half of Andromeda, Hubble has taken nearly 7 400 exposures of the galaxy.

Unlike a digital camera that takes a single photograph in red, green and blue light to create a single full-colour image, Hubble takes monochrome images at specific wavelengths of light. These specific wavelengths can reveal characteristics of an object that are of scientific interest, such as the presence of a particular chemical element. Multiple observations at different wavelengths can be combined to form a single image that reveals all of these characteristics at once but doesn't necessarily contain the full spectrum of visible light. In those cases, colours are assigned to each wavelength to highlight the different characteristics, offering a deeper understanding of the object's properties.

Additionally, Hubble is equipped to take infrared and ultraviolet images, which can reveal information that cannot be obtained using only visible light. Because infrared and ultraviolet light are not visible to human eyes, these images need to be processed in such a way that makes them meaningful to observers. This is done by assigning colours that humans can perceive to the wavelengths that they cannot.

Whether their tool of choice is a sophisticated ground-based telescope, a decent pair of binoculars, or simply their naked eyes, observers hunting for Messier objects can use the data gathered from Hubble's spectacular images to deepen their understanding of these 110 highlights of the night sky as they carry on the tradition of amateur astronomy.

The brilliant stars seen in this ground-based image are members of the open star cluster M45, also known as the Pleiades, or Seven Sisters. The shapes overlaid on the image represent the fields of view of Hubble's cameras and other science instruments, and provide a scale to Hubble's very narrow view on the heavens.
Credits: NASA, ESA and AURA/Caltech

These are some of the best images from Hubble's Messier catalogue taken thus far.

THE CRAB NEBULA OR M1

In 1054, Chinese astronomers took notice of a 'guest star' that was, for nearly a month, visible in the daytime sky. The 'guest star' they observed was actually a supernova explosion, which gave rise to the Crab Nebula, a six-light-year-wide remnant of the violent event.

With an apparent magnitude of 8.4 and located 6 500 light-years from Earth in the constellation Taurus, the Crab Nebula can be spotted with a small telescope and is best observed in January. The nebula was discovered by English astronomer John Bevis in 1731, and later observed by Charles Messier who mistook it for Halley's Comet. Messier's observation of the nebula inspired him to create a catalogue of celestial objects that might be mistaken for comets.

This large mosaic of the Crab Nebula was assembled from 24 individual exposures captured by Hubble over three months. The colours in this image do not match exactly what we would see with our eyes but yield insight into the composition of this spectacular stellar corpse. The orange filaments are the tattered remains of the star and consist mostly of hydrogen. The blue in the filaments in the outer part of the nebula represents neutral oxygen. Green is singly ionized sulphur, and red indicates doubly ionised oxygen. These elements were expelled during the supernova explosion.

A rapidly spinning neutron star (the ultra-dense core of the exploded star) is embedded in the centre of the Crab Nebula. Electrons whirling at nearly the speed of light around the star's magnetic field lines produce the eerie blue light in the interior of the nebula. The neutron star, like a lighthouse, ejects twin beams of radiation that make it appear to pulse 30 times per second as it rotates.

NASA, ESA, J. Hester and A. Loll (Arizona State University)

The heart of the Crab Nebula (M1)

THE HEART OF THE CRAB NEBULA (M1)

Peering deep into M1, this spectacular Hubble image captures the nebula's beating heart: the rapidly spinning pulsar at its core. Bright wisps are moving outward from the pulsar (the rightmost of the two bright stars near the centre of the image) at half the speed of light to form an expanding ring. These wisps form along magnetic field lines in a gas of extremely energetic particles driven into space by the highly magnetised, rapidly rotating neutron star.

Credit: NASA and ESA

Acknowledgment: J. Hester (ASU) and M. Weisskopf (NASA/MSFC)

The Lagoon Nebula (M8)

THE LAGOON NEBULA (M8)

Commonly known as the Lagoon Nebula, M8 was discovered in 1654 by the Italian astronomer Giovanni Battista Hodierna, who, like Charles Messier, sought to catalogue nebulous objects in the night sky so they would not be mistaken for comets. This star-forming cloud of interstellar gas is located in the constellation Sagittarius and its apparent magnitude of 6 makes it faintly visible to the naked eye in dark skies. The best time to observe M8 is during August.

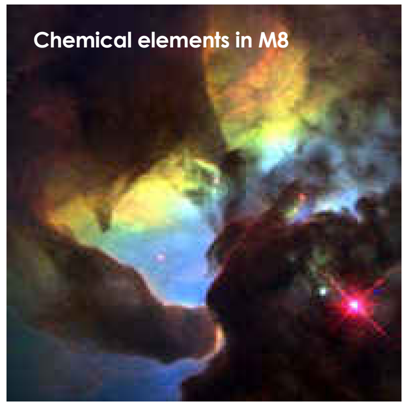
Located 5 200 light-years from Earth, M8 is home to its own star cluster: NGC 6530 (not visible in the image). The massive stars embedded within the nebula give off enormous amounts of ultraviolet radiation, ionising the gas and causing it to shine.

In Hubble's image of the centre of the Lagoon Nebula, dust masks most of the objects within. This image maps the emission from the nebula's ionised gas. Hydrogen is coloured red and nitrogen is green. The blue-white flare at the upper left of the image is scattered light from a bright star just outside the field of view. *Credit: NASA, ESA*

COMBINED IMAGES OF M8

Combining observations in infrared and visible light, Hubble cut through some of M8's dust to reveal stars hiding within this portion of the nebula. The bright star near the centre of the image is Herschel 36. This hot star is the primary source of ionising radiation in M8, which sculpts the nebula's celestial landscape. *Credit: NASA, ESA, J. Trauger (Jet Propulsion Laboratory)*

Combined images of M8



Chemical elements in M8

CHEMICAL ELEMENTS IN M8

This stunning Hubble image maps the chemical elements in a small region of the Lagoon Nebula known as the Hourglass. Blue represents oxygen, green represents hydrogen and red stands for sulphur. Each of the eerie, tornado-like funnels toward the centre of the image is roughly one-half light-year long and both appear to be twisting. The bright star at the bottom right of the image is Herschel 36.

Credit: A. Caulet (ST-ECF, ESA) and NASA

M31

M31

Hubble's M31 mosaic image, taken by the Panchromatic Hubble Andromeda Treasury (PHAT) program, is shown in context with a ground-based image of the entire galaxy. Despite the size of Hubble's massive mosaic, it does not span even half of the galaxy.

Image Credit: NASA, ESA, and Z. Levay (STScI/AURA)

PHAT Mosaic Credit: NASA, ESA, J. Dalcanton, B.F. Williams, and L.C. Johnson (University of Washington), the PHAT team, and R. Gendler

Credit for Ground-based Background Image of M31: (c) 2008 R. Gendler, Used with Permission

ORION NEBULA (M42)

Believed to be the cosmic fire of creation by the Maya of Mesoamerica, M42 blazes brightly in the constellation Orion. Popularly called the Orion Nebula, this stellar nursery has been known to many different cultures throughout human history. The nebula is only 1 500 light-years away, making it the closest large star-forming region to Earth and giving it a relatively bright apparent magnitude of 4. Because of its brightness and prominent location just below Orion's belt, M42 can be spotted with the naked eye, while offering an excellent peek at stellar birth for those with telescopes. It is best observed during January.

The Mayan culture's likening of the Orion Nebula to a cosmic fire of creation is very apt. The nebula is an enormous cloud of dust and gas where vast numbers of new stars are being forged. Its bright, central region is the home of four massive, young stars that shape the nebula. The four hefty stars are called the Trapezium because they are arranged in a trapezoidal pattern. Ultraviolet light unleashed by these stars is carving a cavity in the nebula and disrupting the growth of hundreds of smaller stars.

This stunning Hubble image offers the sharpest view of the Orion Nebula ever obtained. Created using 520 different Hubble exposures taken in multiple wavelengths of light, this mosaic contains over one billion pixels. Hubble imaged most of the nebula, but ground-based images were used to fill in the gaps in its observations. The orange colour in the image can be attributed to hydrogen, green represents oxygen, and the red represents both sulphur and observations made in infrared light.

NASA, ESA, M. Robberto (Space Telescope Science Institute/ESA) and the Hubble Space Telescope Orion Treasury Project Team

Orion Nebula (M42)

The Spiral Galaxy - M66

THE SPIRAL GALAXY – M66

In 1780, Charles Messier discovered spiral galaxy M66 along with its neighbour M65, both of which belong to the Leo Triplet of galaxies. (The third member, NGC 3628, was discovered by William Herschel in 1784 and is not included in the Messier catalogue). M66 is located 35 million light-years from Earth in the constellation Leo and has an apparent magnitude of 8.9. Best observed during April, M66 can be spotted with a small telescope.

Showing a large portion of M66, this Hubble photo is a composite of images obtained at visible and infrared wavelengths. The images have been combined to represent the real colours of the galaxy.

This view highlights the fascinating anatomy of M66. Because the galaxies in the Leo Triplet interact with one another, each has an effect on its neighbours' structures. M66 displays asymmetric spiral arms and a core that appears to be off centre – features likely caused by the gravitational pull of the other two galaxies in the Leo Triplet.

Credit: NASA, ESA and the Hubble Heritage (STScI/AURA)-ESA/Hubble Collaboration

Acknowledgment: Davide De Martin and Robert Gendler

THE TRAPEZIUM CLUSTER

Appearing like glistening precious stones, M42's Trapezium Cluster, named for the trapezoidal arrangement of its central massive stars, is seen in this infrared Hubble image. All of the members of the Trapezium were born together in this hotbed of star formation.

K.L. Luhman (Harvard-Smithsonian Center for Astrophysics, Cambridge, Mass.); and G. Schneider, E. Young, G. Rieke, A. Cotera, H. Chen, M. Rieke, R. Thompson (Steward Observatory, University of Arizona, Tucson, Ariz.) and NASA/ESA

The Trapezium Cluster

Elliot Formation caves in Lesotho. *Wikimedia Commons*

How we used the Earth's magnetic field to date rocks rich in dinosaur fossils

By Lara Sciscio.

Covering two-thirds of South Africa, the Karoo Basin, visually, is a beautiful space. When looking more deeply into its rock layers, like leafing through the pages of a book, one can read about a wealth of palaeoenvironmental and biological processes.

The Karoo Basin is an invaluable archive of information over its 120 million-year depositional history. Rich in fossils, both plants and animals, the Karoo Basin records crisis periods – mass extinction events – in the distant past when many species became extinct.

So far, there have been five main mass extinction events globally. The biggest, the end-Permian, about 252 million years ago, was the Earth's largest ecological disaster. The Karoo Basin also holds evidence of the third largest mass extinction. This occurred at the end of the Triassic, about 200 million years ago, and heralded the rise of the dinosaurs.

Understanding these climate change events and their impact on biology in the Karoo Basin could influence the way we look at the sixth extinction, which is happening now: the Anthropocene.

Scientists need to know when the ancient extinctions happened and for how long. These events are recorded in layers of rock. So we need to know the age of those rocks. There are certain 'geological clocks' which help when dating rocks: a mineral called zircon is one. Fossil pollen and spores are others. But when these are scarce, we need another way of measuring the age of rocks. And the Earth's own magnetic field provides a useful source.

A DIFFERENT TECHNIQUE

My colleagues and I were interested in the age of a specific rock unit in the Karoo Basin: the Elliot Formation. Rocks of the Elliot Formation outcrop in a ring around the Drakensberg Plateau (see figure). The Elliot Formation contains many fossils that shed light on the existence and evolution of dinosaurs in southern Africa.

This is especially interesting as the Formation is thought to span the end-Triassic mass extinction event. However, the age of the Elliot Formation and where this extinction event occurred within its rock layers was debated.

As there are no radiometric dates from zircons for the Elliot Formation, we used the Earth's ancient geomagnetic field as a dating tool. This technique has been used globally on similar aged rocks. Applying it here enabled us to narrow down the age of the Elliot Formation to somewhere between about 213 million and 195 million years old.

These dates may help us to answer broader questions relating to the severity of the end-Triassic mass extinction and the post-extinction recovery period in southern Africa. This time line is particularly useful in measuring the diversity of dinosaurs across the bio-crisis and during a critical time in their evolution.

MAGNETIC FLIPS

The Earth generates and sustains a magnetic field through the motion of the liquid outer core. Some minerals in rocks are able to record the Earth's magnetic field when they are deposited. Two such minerals, hematite and maghemite, are prevalent in the Elliot Formation. In fact, they lend the formation a distinct brick-red colour.

Our research has found that minerals within the rocks of the Elliot Formation are able to retain primary magnetisations: they have reliably recorded the Earth's magnetic field at the time of their deposition. That's important because natural processes can cause 'overprinting' – wiping out the original magnetic signature.

This method has been used within the Karoo Basin before on older rocks, but it's never guaranteed that rocks will retain their primary magnetic signatures. The fact that the Elliot Formation, largely, didn't fall prey to overprinting is what allowed us to record the pattern of the ancient magnetic field.

POLE REVERSAL OFFERS TIMING TOOL

The Earth's magnetic field is not constant through time. It 'flips' or 'reverses' at irregular intervals; on average, every few million years.

When this happens, the magnetic North Pole is direct to the geographic South Pole and *vice versa*. Rocks contain alternating layers of north- and south-directed minerals corresponding to every flip event. This creates distinct geomagnetic polarity chron(s) – a name to define a specific unit of time during reversals – for any given time period.

By studying the rates and number of these reversals recorded in the Elliot Formation's rocks, we are able to get a more accurate idea of the rocks' age.

The next step in pinpointing the Elliot Formation's relative age was to build its unique magnetic polarity time scale – a log of all the reversal events.

This involved drilling out small samples of rock, using a portable hand-held drill, and orientating them, using a special compass in the field. Thereafter samples were processed in the Paleomag Lab at the University of Johannesburg to recover their unique geomagnetic polarity history.

By doing this, we could build a composite magnetic polarity chronology for the Elliot Formation. We were then able to compare these rocks from South Africa and neighbouring Lesotho to others of a similar time period globally. In so doing, the Elliot Formation records the Earth's magnetic field as it was about 200 million years ago.

We are not the only ones trying to pin down this important rock unit's age. We hope that our work will provide a framework on which to place other kinds of information produced by others in this and related fields.

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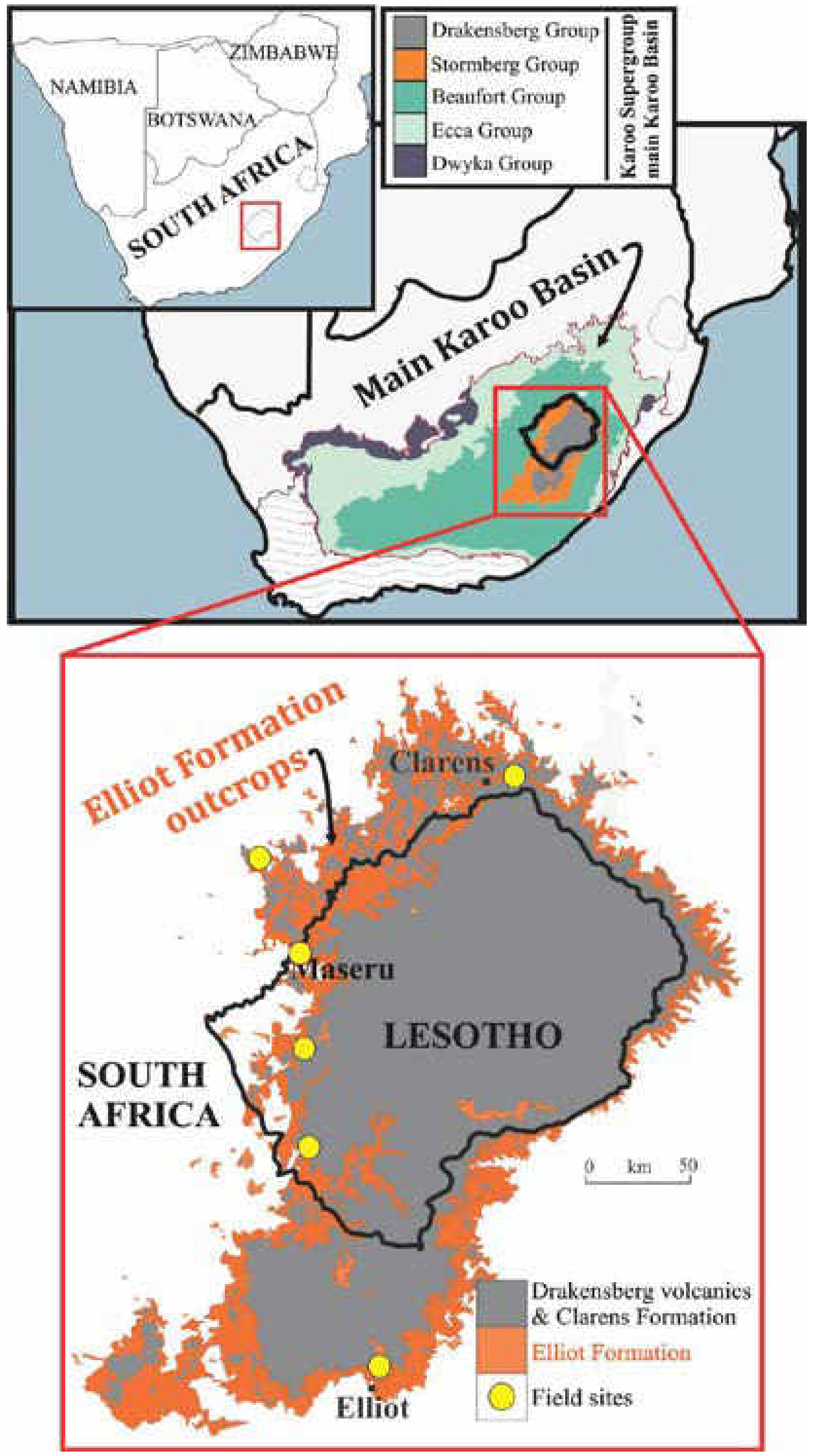
Lara Sciscio is a Postdoctoral Research Fellow in Geological Sciences, University of Cape Town.



The position of the Karoo Basin and the Elliot Formation. *Lara Sciscio*

FORGOTTEN FOSSILS

HOLD CLUES TO HOW ANCESTORS OF MAMMALS CARED FOR THEIR YOUNG

We all know that mammals protect and care for their young. In some cases, they also live within complex social groups. Was this always the case? By Sandra Jasinoski and Fernando Abdala.

The skeletal anatomy of mammals' early ancestors has been studied for more than 150 years. But until relatively recently, not much was known about their lifestyle or reproductive habits. It wasn't clear whether these extinct animals protected and cared for their young in the same way as modern mammals do.

But a few decades ago a clue to their behaviour was discovered in two remarkable fossils found in South Africa that date back 251 million years ago. The significance of these fossils of *Thrinaxodon liorhinus* and *Galesaurus planiceps* has been largely forgotten by the palaeontological community and they were left out of recent discussions about parental care in the fossil record. We rediscovered them while doing other research and decided to reinvestigate their significance.

The fossils are even more important than we imagined. They provide direct evidence of parental care in these extinct animals. They also reveal complex behaviour in our own distant ancestors.

THE FIRST DISCOVERIES

The *Thrinaxodon* and *Galesaurus* fossils date back to the Early Triassic period, soon after the end-Permian mass extinction and before the age of dinosaurs.

Mammals hadn't yet evolved. But their ancestors, the non-mammalian cynodonts, had a few features we recognise today in mammals: teeth differentiated into incisors, canines and complex postcanines, and the presence of a secondary palate. The fossils of *Thrinaxodon* and *Galesaurus* represented the first possible cases of parental care reported in non-mammalian cynodonts. This is significant because mammals didn't evolve for another 30 million years.

The *Thrinaxodon* fossil was found in 1954 by the renowned Karoo fossil hunter James Kitching. Dr AS Brink, a palaeontologist at Johannesburg's University of the Witwatersrand (Wits), briefly described it as consisting of an adult skull preserved next to a small juvenile about a third of its size. Brink hypothesised that this represented a case of parental care.

In 1965 Brink discovered a second case of parental care in *Galesaurus planiceps*, a larger basal cynodont about the size of a fox. The *Galesaurus* fossil block contained the skeleton of an adult surrounded by juveniles. Brink interpreted this fossil as evidence of a mother caring for her young.

These remarkable fossils became part of the collection of the Evolutionary Studies Institute at Wits. We came across them while investigating ontogenetic growth in *Thrinaxodon* and *Galesaurus*. We wanted to find out how these cynodonts' skull changed as they grew from a small juvenile into a large adult. In the course of our work, we realised that these fossils were also telling a forgotten story about nurturing behaviour in our very distant ancestors.

CYNODONTS

The cynodonts are therapsids that first appeared in the Late Permian – approximately 260 million years ago. The group includes modern mammals (including humans) as well as their extinct ancestors and close relatives. Non-mammalian cynodonts were widespread across Gondwana, with fossils found in South America, Africa, India and Antarctica. Fossils have also been found in eastern North America, Belgium and northwestern France.

ONTOGENETIC GROWTH

Ontogeny is the word used to describe the development of an organism, usually from the time of fertilisation of the egg, to the organism's mature form. The word can also be used to refer to the study of the whole of an organism's lifespan. Ontogenetic changes are found as organisms grow.

Some further work had been done on the *Thrinaxodon* fossil since Brink's 1955 description. The skulls are now separated from each other and acid-preparation led to the discovery of a second juvenile individual. But the *Galesaurus* fossil was found tucked away in a drawer in collections, with no evidence of further preparation or study.

We were intrigued, and decided to reinvestigate what the fossils might tell us about parental care among the ancestors of mammals.

OUR FINDINGS

Our study concluded that in both cases there were two young juveniles associated with each adult.

We then investigated more than 100 fossils of *Thrinaxodon* and *Galesaurus* from South Africa to determine how often individuals of each genus were preserved together. The bones of individuals that were found together in the same fossil block or in close proximity were, in many cases, preserved in 'life position'.

This suggests that these animals were living together in a group – what's known as an aggregation – before they died and were fossilised.

The research we'd already done into ontogenetic classification really helped. We had sorted the *Thrinaxodon* and *Galesaurus* specimens into juvenile, subadult, or adult stages. This meant we could determine whether the aggregation consisted of individuals of the same age – for example, all adults – or represented a mixed-age group, such as an adult with juveniles.

Overall, we found that *Thrinaxodon* had a higher occurrence of aggregations than *Galesaurus*. These groups were comprised of individuals of either similar or different ontogenetic ages.

In *Thrinaxodon*, we found four aggregations consisting of same-age individuals and three aggregations among mixed-age individuals – including the parental care case described by Brink.

This is in stark contrast to *Galesaurus*: here, only one other aggregation, among three sub-adult individuals, was found in addition to the parental care case. These findings suggest that *Thrinaxodon* regularly lived within a group.

The two parental care fossils Brink described showed the largest discrepancy in size among aggregating individuals. This implies he was right: these fossils do indeed represent cases of parental care.

The juveniles in each parental care fossil represent the smallest recorded individuals for both genera, suggesting they were newborns. In addition, the juveniles of each genus are similar in size to each other. That indicates they might have been siblings. We also confirmed that the adult *Galesaurus* individual represented a 'female' – so, a mother – based on our previous discovery of sexual dimorphism in this genus.

PARENTING IN THE PAST

Parental care was present in both of these cynodonts, but the evidence to date suggests that *Galesaurus* cared for its young for a relatively longer period of time. This is because the skull of the *Galesaurus* juveniles is about half the size of the largest known adult, and it is relatively much larger than the *Thrinaxodon* juveniles. This discrepancy in size also supports our previous idea that *Thrinaxodon* matured relatively earlier than *Galesaurus*.

What these fossils show is that parental care instincts were already established 251 million years ago in two different species of mammal forerunners. This indicates that complex behaviour generally attributed to living mammals has a long history, stretching back millions of years.

***Galesaurus* parental care fossil consisting of one adult surrounded by two juveniles.** *From Jasinoski and Abdala (2017). DOI: 10.7717/peerj.2875/fig-3*

***Thrinaxodon liorhinus*, an early triassic cynodont of South Africa.**
Nobu Tamura, Wikimedia Commons

Complex **life evolved** out of the chance coupling of small molecules

Complex life, as we know it, started completely by chance, with small strands of molecules linking up, which eventually would have given them the ability to replicate themselves.

In this world, billions of years ago, nothing existed that we would recognise today as living. The world contained only lifeless molecules that formed spontaneously through the natural chemical and physical processes on Earth.

However, the moment that small molecules connected and formed larger molecules with the ability to replicate themselves, life started to evolve.

'Life was a chance event, there is no doubt about that,' says Dr Pierre Durand from the Evolution of Complexity Laboratory in the Evolutionary Studies Institute at Wits University, who led a project to find out how exactly these molecules linked up with each other. Their results were published in September this year in the journal Royal Society OS, in a paper entitled *Molecular trade-offs in RNA ligases affected the modular emergence of complex ribozymes at the origin of life.*

Very simple ribonucleic acid (RNA) molecules (compounds similar to deoxyribonucleic acid (DNA)) can join other RNA molecules to themselves through a chemical reaction called ligation. The random joining together of different pieces of RNA could give rise to a group of molecules able to produce copies of themselves and so kick-start the process of life.

While the process that eventually led to the evolution of life took place over a long period of time, and involved a number of steps, Wits PhD student Nisha Dhar and Durand have uncovered how one of these crucial steps may have occurred.

They have demonstrated how small non-living molecules may have given rise to larger molecules that were capable of reproducing themselves. This path to self-replicating molecules was a key event for life to take hold.

'Something needed to happen for these small molecules to interact and form longer, more complex molecules, and that happened completely by chance,' says Durand.

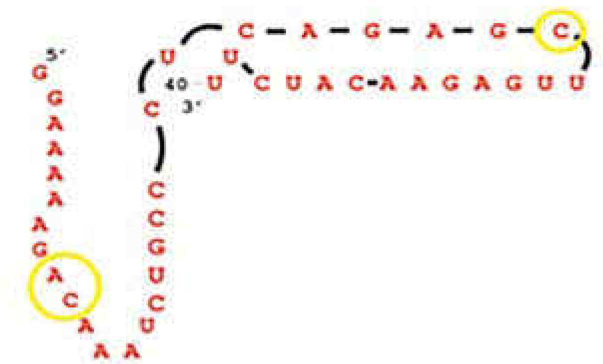
These smaller RNA molecules possessed enzyme activity that allowed ligation, which, in turn allowed them to link up with other small molecules, thereby forming larger molecules.

'The small molecules are very promiscuous and can join other pieces to themselves. What was interesting was that these smaller molecules were smaller than we had originally thought,' says Durand.

The smallest molecule that exhibited self-ligation activity was a 40-nucleotide RNA. It also demonstrated the greatest functional flexibility as it was more general in the kinds of substrates it ligated to itself although its catalytic efficiency was the lowest.

'Something needed to happen for molecules to reproduce, and thereby starting life as we know it. That something turned out to be the simple ligation of a set of small molecules, billions of years ago,' says Durand. *Issued by Wits University marketing and communications.*

Dr Pierre Durand, project leader of the Evolution of Complexity Laboratory in the Evolutionary Studies Institute at Wits University. *Wits University*



A simple RNA molecule such as this may have been responsible for the evolution of complex life as we know it. *Wits University*

Ancient, lost, mountains in the Karoo reveal the **secrets of massive extinction** event over 250 million years ago

Millions of years ago, a mountain range that would have dwarfed the Andes mountains in South America, stretched over what is currently the southern-most tip of Africa.

Remnants of these mountains – called the Gondwanides, after the massive supercontinent, Gondwana over which it stretched – once spanned the southern continents of South America, Antarctica, South Africa and Australia, and parts of it now form the mountains near Cape Town in South Africa.

It is in the shadows of these ancient mountains that Dr Pia Viglietti, a post-doctoral fellow at the Evolutionary Studies Institute (ESI) at Wits University, found the secrets of one of the biggest mass extinction events that Earth has ever seen.

'We've established that climatic changes related to the devastating end of the Permian mass extinction event about 250 million years ago were beginning earlier than previously identified,' says Viglietti.

The Permian-Triassic extinction was one of Earth's largest extinction events, in which up to 96% of all marine species and 70% of terrestrial vertebrate species became extinct.

For her PhD, Viglietti studied the fossil-rich sediments present in the Karoo, deposited during the tectonic events that created the Gondwanides, and found that the vertebrate animals in the area started to either go extinct or become less common much earlier than was previously thought. Her research was published in *Nature Scientific Reports*.

'The Karoo Basin takes up a huge portion of South Africa and most of us who drive through it do not think much of it,' says Viglietti. 'But if you know what you're looking for, the Karoo represents a wealth of knowledge about the story of life on Earth.'

The Karoo tells a 100 million-year long story of the supercontinent Gondwana, and if you can read this rock record you will find the story of the life and death of the animals it supported.

'The Gondwanides not only influenced how and where rivers flowed (depositing sediment), they also had a significant effect on the climate, and thus the ancient fauna of the Karoo Basin,' says Viglietti.

Large mountain ranges put a lot of weight on the Earth's crust, creating a depression in the crust. This can be described by using the analogy of a person standing on the edge of a diving board. The person represents the 'load' (or weight) of the mountain while the diving board is the Earth's crust. The depression causes sediment to accumulate around the mountain's base. It is in this sediment where rocks and fossils are preserved.

As mountains erode, they put less weight on the Earth's crust, and the depression decreases, just like the diving board would react to the diver jumping off it. This was the effect that the Gondwanides had on the sedimentation in the Karoo Basin over 100 million years. The traces of this tectonic dance are preserved by periods of deposition and non-deposition.

'During my PhD, I have identified a new tectonic "loading" event (mountain building event) that kick-started sedimentation in the Latest Permian Karoo Basin,' says Viglietti.

The sediments during this loading event also provided evidence of climatic changes as well as evidence of a previously overlooked 'faunal turnover', that points to the start of the end-Permian mass extinction event.

'Within the last million years before this major biotic crisis, the animals had already started to react. I interpret this faunal change as resulting from climatic effects relating to the end-Permian mass extinction event – only occurring much earlier than previously identified,' says Viglietti.

Dr Pia Viglietti. *Wits University*

Remnants of the massive Gondwanides mountain range that spanned across five continents over 250 million years ago, can still be found in South Africa's Karoo region. *Pia Viglietti*

Herding for health

The Herding for Health project that was initiated by the Faculty of Veterinary Science at the University of Pretoria (UP) is a One Health, pro-poor, rural development project aimed at establishing integrated management of livestock and improving rural livelihoods in areas at the wildlife-livestock interface.

The Kruger to Canyon Biosphere Reserve (K2C), located on the western border of the Kruger National Park (KNP), is world famous for its abundance of wildlife and natural beauty. The reserve is situated in the KNP's buffer zone, where, through collaborative partnerships, it drives the integrated land use strategy of SANParks to enable responsible, community-based use of natural resources and wildlife management that is aligned to the KNP's socioeconomic development plans.

In this natural wonderland, however, pastoralist communities bear the burden of living so close to wildlife. Cattle farmers routinely suffer losses of livestock to predation from both small and large predators that cross the park fence boundary, and their animals are also at higher risk of contracting multi-host pathogens and infectious trans-boundary animal diseases, such as foot-and-mouth disease (FMD), which is spread from buffalo to cattle. Although this viral disease does not pose a risk to food safety or public health, it can spread quickly among cloven-hoofed livestock, and is therefore difficult to control. Areas where FMD is endemic in wildlife, or the risk of spread to livestock is high, are demarcated as 'FMD infected/protection zones', and livestock movement, as well as the transport of most meat products from cattle, is restricted within and between these areas.

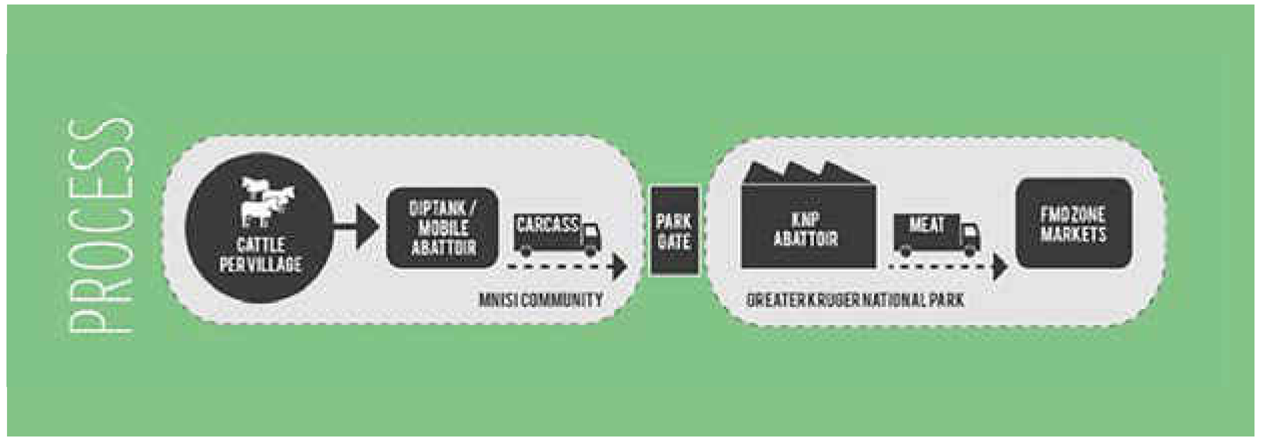
Apart from the imposed movement control of all susceptible animals, FMD is further controlled by restricting contact between buffalo and livestock. This is achieved by keeping wildlife in game-proof, fenced areas within protected areas such as the greater KNP. Unfortunately, this restricted movement of cattle and most beef products negatively impacts market access for local cattle farmers and thus their ability to make money from their cattle. The inability of farmers living in the FMD protection zone of the K2C to sell their cattle or move them from the area also results in rangeland degradation, as well as significant losses of livestock during periods of drought.

The Herding for Health project aims to respond to these and other pressing challenges, and to alleviate poverty among the local communities. Over the last five years, the university has engaged a range of partners who now collaborate under the banner of Herding for Health.

Herd monitors (with knowledge of primary animal health) and eco rangers (herders with training in environmental and livestock management), for example, work with scientists, local government departments such as veterinary services, and local communities to improve livestock production while restoring degrading rangelands. In addition to the rangeland restoration, the Herding for Health partners also support local farming cooperatives to take advantage of economic opportunities and improve their livelihoods through activities linked to sustainable red meat production, such as game meat harvesting, grazing/grass harvesting rights, seed harvesting for rangeland improvement and trade in livestock and wildlife-derived products.

The Mnisi area (Bushbuckridge Municipality, Mpumalanga), which has a long history of working with the Faculty of Veterinary Science at UP and its conservation and development partners, was selected to pilot a project that aims to provide opportunities for livestock sales to farmers in an FMD protection zone. The communities living in this area are surrounded by wildlife areas on three sides of their grazing lands, which puts them at especially high risk. The pilot project, which includes four villages and four communal dip tanks (to avoid cattle contracting FMD or other diseases), 7 500 hectares of rangeland, 4 000 cattle, and 330 cattle owners, will also introduce a new design of mobile abattoir technology that will facilitate the safe and low-impact supply of red meat from livestock living in an FMD-infected area.

Livestock grazing near a herd of elephants. *University of Pretoria*



The Herding for Health process. *University of Pretoria*

Dr Jacques van Rooyen, from the Faculty's Hans Hoheisen Wildlife Research Platform (HHWRP), says that his team has been working around the clock to try and get all the necessary approvals and costing in place for this new addition to the project. 'It is becoming a benchmark project in terms of how science, development, policy, implementation and business need to come together to achieve what science proposes could work. It has been very challenging to combine all these various facets, but we believe it will be worth it,' he says.

The Mpumalanga Department of Agriculture, Rural Development, Land and Environmental Affairs recently approved the pilot phase of the mobile abattoir technology for 30 cattle. The team will keep detailed records of the process and adhere to strict control measures.

The pilot area is within reach of the Skukuza abattoir, the only designated abattoir in the FMD-infected zone of South Africa from where meat can be transported outside the control area should all veterinary requirements be met. The mobile abattoir technology, together with the successful integration of commodity-based trade standards for the trade of beef from FMD-infected areas, will enable the sale of red meat products outside the controlled areas and provide a vital cash injection for local households that rely on livestock farming for their subsistence.

The Herding for Health pilot project is led by the HHWRP and supported by the Peace Parks Foundation and the Hans Hoheisen Charitable Trust. Implementation of the project is managed in collaboration with Conservation South Africa, whose aim is to promote sustainable agricultural practices through the development of value chains that will in turn promote rangeland and biodiversity stewardship. The Peace Parks Foundation, one of the major contributors to this project, has also pledged major support for the concept and intends to grow it throughout southern Africa. They have already identified possible sites in Mozambique and Zambia for its expansion. All aspects of the Herding for Health programme also require close collaboration with various government departments, such as the Mpumalanga Veterinary Services and the Department of Rural Affairs and Land Reform. These departments will form part of the development team, especially where new policy and implementation models are being tested.

Issued by University of Pretoria: Research Matters. By Ansa Heyl.

Africa's largest eagle in free fall

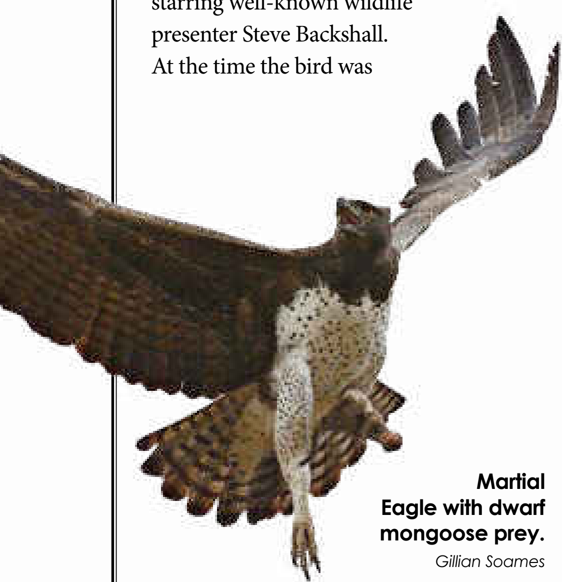
The population of Africa's largest eagle species is in freefall in South Africa, and may be soaring towards extinction, according to a new University of Cape Town (UCT) study based on changes in sighting rates over the last 20 years.

Martial Eagle sightings have dropped by as much as 60% since the late 1980s, in stark contrast to human population growth across their shared natural habitat, said the study published this week in the journal *Bird Conservation International*. Although the exact reasons for the decline remain unclear, researchers say their findings point to an urgent need to better understand the threats to this iconic bird.

Worryingly, the study also highlighted a marked decline in Martial Eagle sightings within protected areas, including in the world-famous Kruger National Park and the Kgalagadi Transfrontier Park. However, declines of the species in protected areas were not as severe as elsewhere, suggesting that these areas could act to buffer the factors leading to declines.

Martial Eagles mainly prey on large birds and reptiles, and small and medium-sized mammals, but are strong enough to prey on small antelopes. They typically nest in high treetops.

Their plight made international headlines last year when Mozambican hunters killed an adult bird that had featured in a British documentary starring well-known wildlife presenter Steve Backshall. At the time the bird was being tracked via a GPS satellite tag.



Martial Eagle with dwarf mongoose prey. *Gillian Soames*

Martial Eagle with roller. *Rene van der Schyff*

Martial Eagle. *Megan Murgatroyd*

The research was conducted by Dr Arjun Amar and PhD student Daniël Cloete from UCT's FitzPatrick Institute of African Ornithology, using two Southern African Bird Atlas Project (SABAP) surveys carried out 20 years apart. Their previous research showed that comparing these surveys provided an accurate way of measuring changes in the population size of this eagle species.

Martial Eagle total population figures are still relatively inexact, but their conservation status was uplisted in 2013 from Near Threatened to Vulnerable – which means they are recognised to be globally threatened. The study published this week provides the most accurate assessment for the decline of the species in any African country and was only possible due to an army of volunteer birdwatchers that contribute their sightings to the SABAP database.

The study found significant declines in three provinces; these were Kwa-Zulu Natal, Mpumalanga and Limpopo. Changes differed across the biomes (distinct regions with similar geography and climate), with the species faring worst in the Grassland, Savannah, Indian Ocean Coastal Belt and the Nama Karoo biomes. However, there was better news in the Fynbos biome of the Western and Eastern Cape, where reporting rates remained more stable over the last 20 years.

'Despite having full legal protection in South Africa, this species is known to be targeted and killed by farmers who blame the species for predation of their livestock, or may be accidentally killed by poison left to kill other predator species,' the authors noted.

Another major threat for the Martial Eagles may be electricity infrastructure such as power lines, particularly among juveniles, which have a wider territorial range.

Dr Amar, the lead author of the study, said 'this analysis was only possible thanks to the efforts of many hundreds of dedicated volunteer birdwatchers who contribute their records to the SABAP survey database.' Dr Amar added 'we have now quantified the decline of the species in South Africa, but that is only the first step, we now need urgent research to better understand the factors which are responsible for causing this iconic species to be lost from our countryside, so that these factors can be better controlled.'

Issued by UCT Communication and Marketing Department.

New improved mosquito traps developed in partnership between UP ISMC and private sector

The University of Pretoria Institute for Sustainable Malaria Control (UP ISMC) is assisting in the design and testing of an innovative solar-powered trap to monitor mosquito populations, especially in areas where malaria and arboviruses require vector control. This joint venture brings together the engineering skills of two private-sector entrepreneurs, Quentin van den Bergh and Kevin Godfrey, with the UP ISMC's Prof. Leo Braack and his knowledge of mosquito ecology and behaviour. The trap is compact, has a suction fan that draws the mosquitoes into a trap-box, and contains a cluster of light-emitting diodes (LEDs) that emit specific visible and invisible wavelengths of light, and uses carbon dioxide as attractant. Power is provided by a small solar panel that doubles as a 'roof' to protect the electronic circuit board below. An added advantage is that the unit also has a power socket to power or charge a USB device such as a mobile phone, notepad or study lamp. This is potentially an incentive for local people assisting in large-scale mosquito surveys or for researchers spending time in remote areas. The battery will easily last overnight, which is the usual trapping time, and battery life is a minimum of three years. Light traps, historically, have depended either on dry-cell disposable batteries that last a few nights before having to be discarded, or rechargeable 6-volt batteries that are bulky and need to be connected to an electrical outlet for several hours of recharging. This new version is a more convenient and practical design and will retail at a comparable price to the older versions.

The Silver Bullet mosquito trap. *University of Pretoria*

Such mosquito traps have multiple purposes. Traps are the standard approach used by entomologists to determine which mosquito species are present in an area and if disease-carrying species are present. Regular standardised trapping in a particular region will reveal seasonal population trends and also some index of population numbers of particular species of *Anopheles* or other potential disease-carrying mosquito species. If mosquito control measures are introduced into that area, the traps can show the impact of these on mosquito numbers. Traps can be used to catch as many vector species as possible to see what percentage of those mosquitoes are actually carrying the disease organisms, and therefore what the risk of disease transmission is in that region. Work is also being done on finding attractant substances to combine with the trap so that very large numbers of mosquitoes can be caught, which directly contributes to a reduction in disease transmission risk, provided of course that enough traps are put out to saturate the region. Most of all, however, mosquito traps are a basic and essential tool of trade for medical entomologists to monitor mosquito populations, in particular species composition, relative abundance, and pathogen presence in these mosquitoes.

For more information on the Silver Bullet Mosquito trap, contact Prof. Leo Braack (leo.braack@up.ac.za), Kevin Godfrey (quentin@projects24.net) or Quentin van den Bergh (quentin@projects24.net).

Issued by University of Pretoria Institute for Sustainable Malaria Control.

NOTHING MATTERS

HOW THE INVENTION OF ZERO HELPED CREATE MODERN MATHEMATICS

A small dot on an old piece of birch bark marks one of the biggest events in the history of mathematics. The bark is actually part of an ancient Indian mathematical document known as the Bakhshali manuscript. And the dot is the first known recorded use of the number zero. What's more, researchers from the University of Oxford recently discovered the document is 500 years older than was previously estimated, dating to the third or fourth century – a breakthrough discovery. By Ittay Weiss.

Today, it's difficult to imagine how you could have mathematics without zero. In a positional number system, such as the decimal system we use now, the location of a digit is really important. Indeed, the real difference between 100 and 1 000 000 is where the digit 1 is located, with the symbol 0 serving as a punctuation mark.

Yet for thousands of years we did without it. The Sumerians of 5 000BC employed a positional system but without a 0. In some rudimentary form, a symbol or a space was used to distinguish between, for example, 204 and 20000004. But that symbol was never used at the end of a number, so the difference between 5 and 500 had to be determined by context.

What's more, 0 at the end of a number makes multiplying and dividing by 10 easy, as it does with adding numbers like 9 and 1 together. The invention of zero immensely simplified computations, freeing mathematicians to develop vital mathematical disciplines such as algebra and calculus, and eventually the basis for computers.

Zero's late arrival was partly a reflection of the negative views some cultures held for the concept of

nothing. Western philosophy is plagued with grave misconceptions about nothingness and the mystical powers of language. The fifth century BC Greek thinker Parmenides proclaimed that nothing cannot exist, since to speak of something is to speak of something that exists. This Parmenidean approach kept prominent historical figures busy for a long while.

After the advent of Christianity, religious leaders in Europe argued that since God is in everything that exists, anything that represents nothing must be satanic. In an attempt to save humanity from the devil, they promptly banished zero from existence, though merchants continued secretly to use it.

By contrast, in Buddhism the concept of nothingness is not only devoid of any demonic possessions but is actually a central idea worthy of much study en route to nirvana. With such a mindset, having a mathematical representation for nothing was, well, nothing to fret over. In fact, the English word 'zero' is originally derived from the Hindi 'sunyata', which means nothingness and is a central concept in Buddhism.

So after zero finally emerged in ancient India, it took almost 1 000 years to set root in Europe, much longer than in China or the Middle East. In 1 200 AD, the Italian mathematician Fibonacci, who brought the decimal system to Europe, wrote that:

'The method of the Indians surpasses any known method to compute. It's a marvellous method. They do their computations using nine figures and the symbol zero.'

This superior method of computation, clearly reminiscent of our modern one, freed mathematicians from tediously simple calculations, and enabled them to tackle more complicated problems and study the general properties of numbers. For example, it led to the work of the seventh century Indian mathematician and astronomer Brahmagupta, considered to be the beginning of modern algebra.

ALGORITHMS AND CALCULUS

The Indian method is so powerful because it means you can draw up simple rules for doing calculations. Just imagine trying to explain long addition without a symbol for zero. There would be too many exceptions to any rule. The ninth century Persian mathematician Al-Khwarizmi was the first to meticulously note and exploit these arithmetic instructions, which would eventually make the abacus obsolete.

Such mechanical sets of instructions illustrated that portions of mathematics could be automated. And this would eventually lead to the development of modern computers. In fact, the word 'algorithm' to describe a set of simple instructions is derived from the name 'Al-Khwarizmi'.

The invention of zero also created a new, more accurate way to describe fractions. Adding zeros at the end of a number increases its magnitude, with the help of a decimal point, adding zeros at the beginning decreases its magnitude. Placing infinitely many digits to the right of the decimal point corresponds to infinite precision. That kind of precision was exactly what 17th century thinkers Isaac Newton and Gottfried Leibniz needed to develop calculus, the study of continuous change.

And so algebra, algorithms, and calculus, three pillars of modern mathematics, are all the result of a notation for nothing. Mathematics is a science of invisible entities that we can only understand by writing them down. India, by adding zero to the positional number system, unleashed the true power of numbers, advancing mathematics from infancy to adolescence, and from rudimentary toward its current sophistication.

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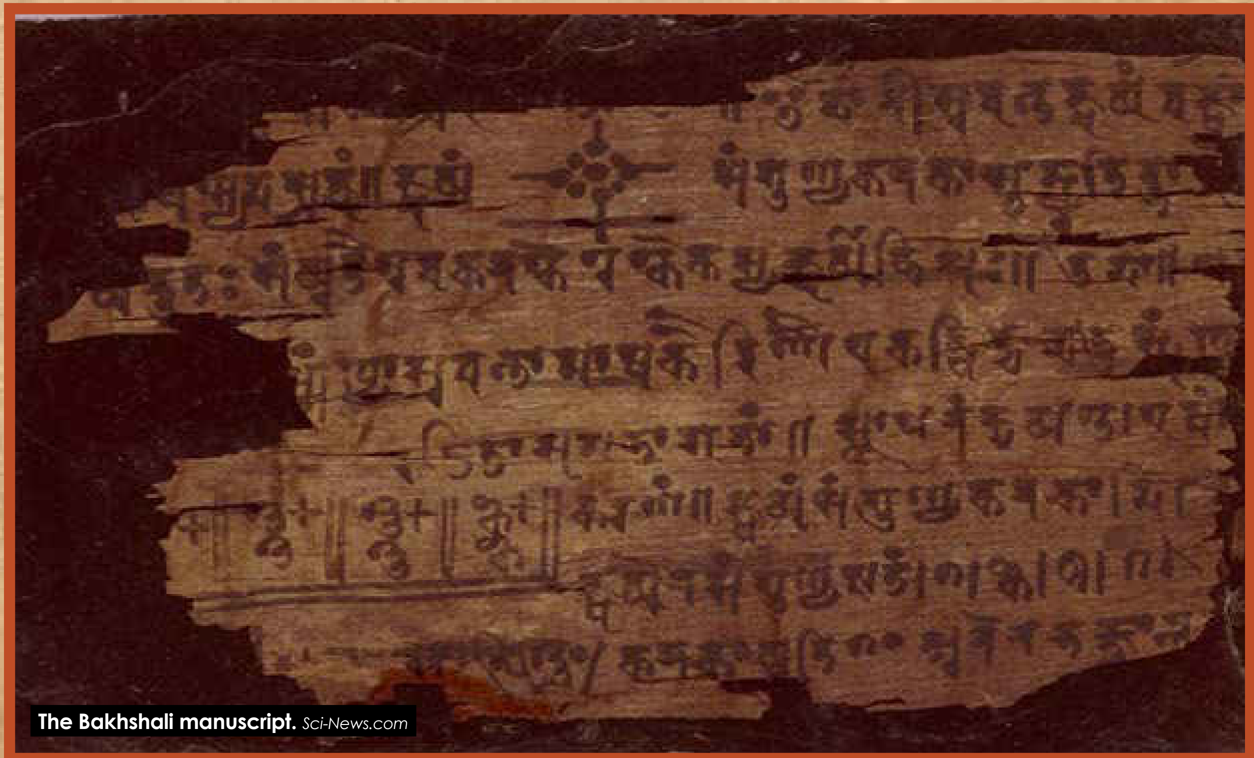


The Bakhshali manuscript. Sci-News.com

The Nobel Prize for physics 2017

'... for decisive contributions to the LIGO detector and the observation of gravitational waves'. Quest looks at the Nobel Prize for physics this year.

This year's Nobel Prize for physics goes to three people – Rainer Weiss, Barry C Barish and Kip S Thorne for the discovery of gravitational waves.

GRAVITATIONAL WAVES FINALLY CAPTURED

On 14 September 2015, the Universe's gravitational waves were observed for the very first time. The gravitational waves that have now been seen were created in an enormous collision between two black holes, more than a thousand million years ago, and 1.3 billion light years from Earth. Albert Einstein was right again – he predicted the existence of gravitational waves in his general theory of relativity 100 years ago.

LIGO, the Laser Interferometer Gravitational-Wave Observatory, is a collaborative project with over 1 000 researchers from more than 20 countries. Together, they have realised a vision that is almost 50 years old. The 2017 Nobel Laureates have, with their enthusiasm and determination, each been invaluable to the success of LIGO. Pioneers Rainer Weiss and Kip S Thorne, together with Barry C Barish, the scientist and leader who brought the project to completion, ensured that four decades of effort led to gravitational waves finally being observed.

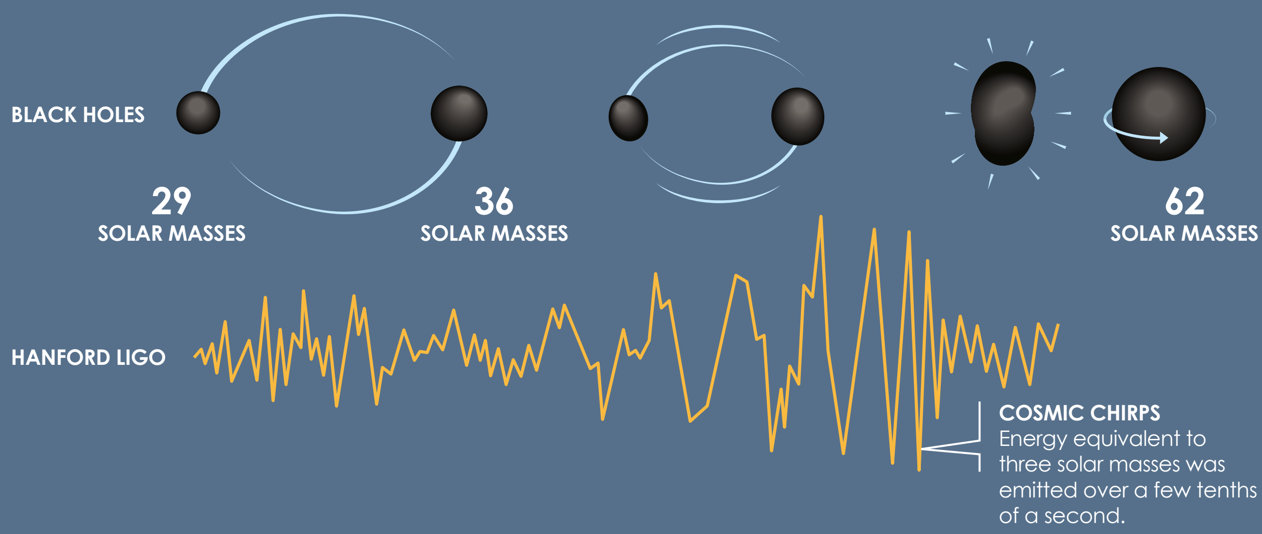
LIGO is an instrument specifically designed to listen to space's gravitational waves. Even if gravitational waves are tremors in spacetime itself, and not sound waves, their frequency is equivalent to those we can hear with our ears. When Einstein described gravitational waves 100 years ago, he explained that space and time can be stretched and changed. In his model, he described spacetime as four dimensional, vibrating with gravitational waves that are always created when a mass accelerates – like when a star explodes in a distant galaxy or a pair of black holes rotate around each other. Although Einstein described black holes in his general theory of relativity, for more than 50 years most researchers were convinced that they only existed as solutions to his equations and were not actually out there in space. The theory of relativity explains gravity as a curvature in spacetime. Where gravity is very, very strong, the curvature can become so great that a black hole forms – the most bizarre objects in spacetime – nothing can escape them, not even light.

The Hanford facility is on the steppes of the northwest USA, outside Hanford. *Courtesy Caltech MIT/Ligo Laboratory*

The Livingston facility is in Livingston in the southern swampland of Louisiana. *Courtesy Caltech MIT/Ligo Laboratory*

LIGO consists of two gigantic identical interferometers. The gravitational wave first hit the interferometer in Livingston and then passed its twin in Hanford, just over 3 000 km away, 7 milliseconds later. The signals were almost identical, and were a good match with the predicted signal for a gravitational wave. Using the signals, an area in the southern skies could also be identified as the area the waves came from. *©Johan Jarnestad/The Royal Swedish Academy of Sciences*

GRAVITATIONAL WAVES FROM COLLIDING BLACK HOLES



The two black holes emitted gravitational waves for many million years as they rotated around each other. They got closer and closer, before merging to become one black hole in a few tenths of a second. The waves then reached a crescendo which, to us on Earth, 1.3 billion light-years away, sounded like cosmic chirps that came to an abrupt stop. *©Johan Jarnestad/The Royal Swedish Academy of Sciences*

Direct evidence of gravitational waves requires direct observations of the waves and spacetime is rigid, so only the most violent cosmic processes can cause gravitational waves large enough to measure. But their amplitude is so tiny that detecting them is like measuring the distance to a star 10 light-years away with a precision equivalent to the diameter of a strand of hair. And, on top of that, most explosive events don't occur in our own galaxy, so we have to look further afield.

GRAVITATIONAL WAVES REVEAL THE PAST

What LIGO detected was the collision of two black holes, which had been moving in circles around each other since they formed, early in the history of the Universe. With every cycle, they swept spacetime into a spiral, a spacetime disturbance which propagated further and further out into space in the form of gravitational waves. These waves carried away energy, making the black holes move closer to each other. The closer they got, the faster they rotated and the more energy was sent out over many millions of years. Finally, in a fraction of a second, the horizons of the black holes touched each other and they merged, almost at the speed of light. As the two black holes merged, all the vibrations died away, leaving a single rotating black hole, with no trace of the dramatic way in which it formed.

Gravitational waves are the 'memory' of the event – ripples of spacetime.

HOW TO CATCH A GRAVITATIONAL WAVE

LIGO is a gigantic interferometer. The first detector for capturing gravitational waves looked like a tuning fork, with two prongs, sensitive to waves of a particular frequency, built in the 1960s. The first observations from this detector could never be replicated, but both Kip Thorne and Rainer Weiss were firmly convinced that gravitational waves could be detected and Weiss designed a detector, a laser-based interferometer. An interferometer is made up of two arms that form an L. At the corner and the end of the L, massive mirrors are suspended. A passing gravitational wave affects the interferometer's arms differently – when one arm is compressed, the other is stretched.

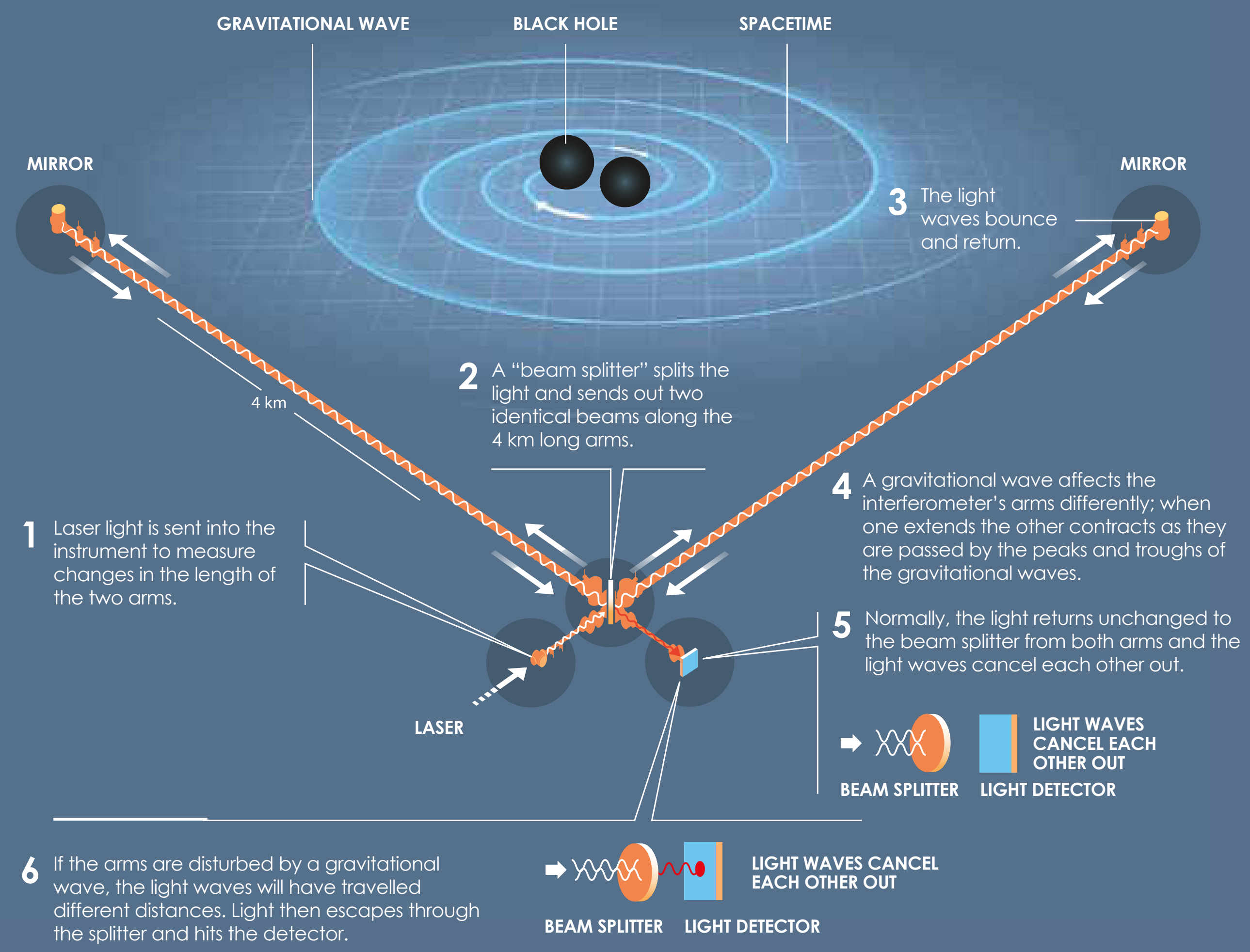
A laser beam bouncing between the mirrors measures the changes in the lengths of the arms. If nothing happens, the bouncing light beams from the lasers cancel each other out when they meet at the corner of the L. But if either of the interferometer's arms changes length, the light travels different distances, so the light waves lose synchronisation and the resulting light's intensity changes where the beams meet.

LIGO is a simple idea that took over 40 years to come to fruition, with the development of two facilities. LIGO is located in the northwest of the USA, outside Hanford, Washington, with a twin facility, 3 000 km to the south in the swamps of Livingston, Louisiana.

So far all sorts of electromagnetic radiation and particles, like cosmic rays or neutrinos, have given us knowledge about the universe. Gravitational waves, however, are a direct way to observe disturbances in spacetime itself. This is something completely new and different, opening up unseen worlds. A wealth of discoveries awaits those who succeed in capturing gravitational waves and interpreting their message.

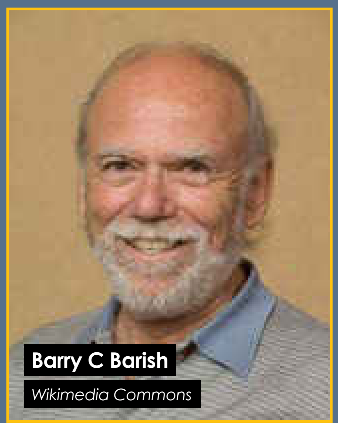
Text adapted from https://www.nobelprize.org/nobel_prizes/physics/laureates/2017/popular-physicsprize2017.pdf.

LIGO – A GIGANTIC INTERFEROMETER

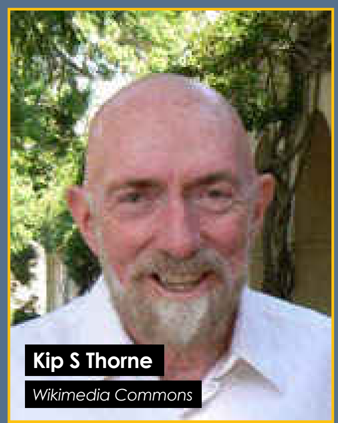


The world's first captured gravitational waves were created in a violent collision between two black holes, 1.3 billion light-years away. When these waves passed the Earth, 1.3 billion years later, they had weakened considerably: the disturbance in spacetime that LIGO measured was thousands of times smaller than an atomic nucleus. *©Johan Jarnestad/The Royal Swedish Academy of Sciences*

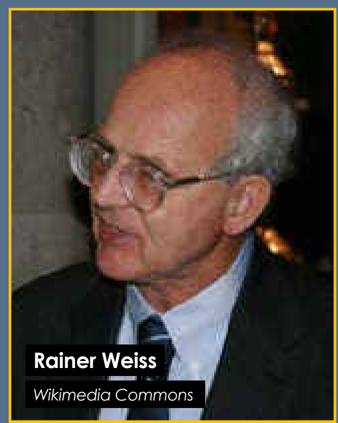
THE NOBEL LAUREATES



Born 1936 in Omaha, NE, USA. PhD 1962 from the University of California, Berkeley, CA, USA. Linde Professor of Physics, California Institute of Technology, Pasadena, CA, USA. *https://labcit.ligo.caltech.edu/~BCBAct*

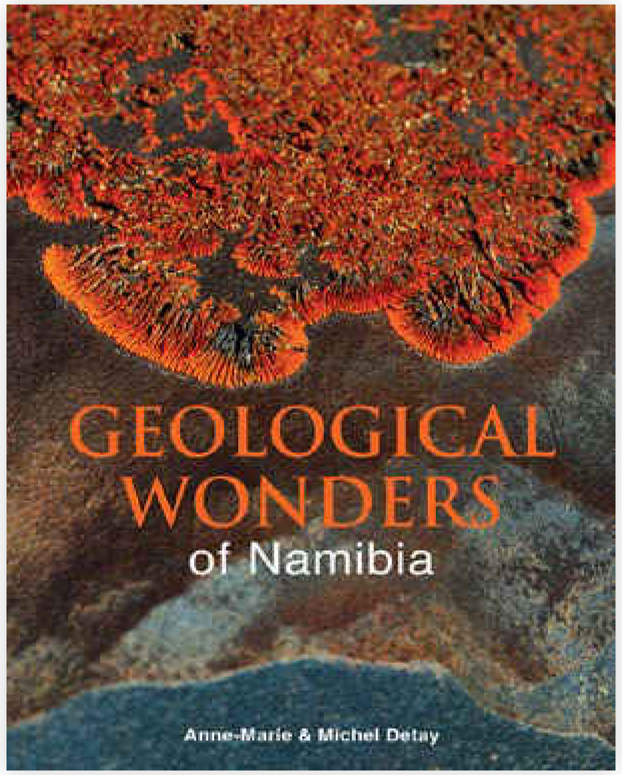


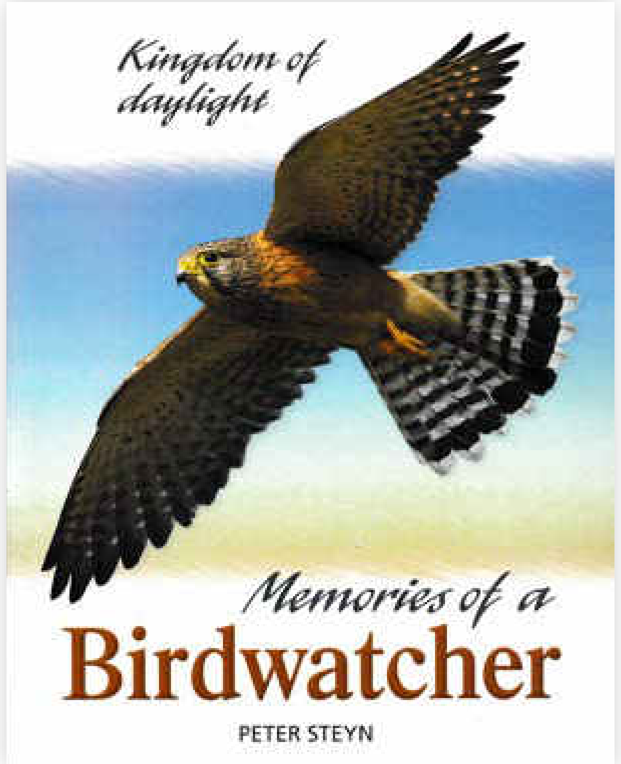
Born 1940 in Logan, UT, USA. PhD 1965 from Princeton University, NJ, USA. Feynman Professor of Theoretical Physics, California Institute of Technology, Pasadena, CA, USA. *https://www.its.caltech.edu/~kip/index.html/*



Born 1932 in Berlin, Germany. PhD 1962 from the Massachusetts Institute of Technology, MIT, Cambridge, MA, USA. Professor of Physics, Massachusetts Institute of Technology, MIT, Cambridge, MA, USA. *http://web.mit.edu/physics/people/faculty/weiss_rainer.html*

BOOK REVIEW





DESERT WONDERS

Geological Wonders of Namibia. By Anne-Marie and Michel Detay. Struik Nature. Cape Town. 2017

The geology of Namibia is almost legendary and this book offers a detailed insight into the formation of this intricate and varied landscape. The chapters are arranged chronologically – starting 13.8 billion years ago and each chapter deals with a particular event or process that resulted in the particular features and landscapes. These include meteorites, canyons, caves, fossils and footprints, volcanoes, granite domes and many other features of this incredible country.

The chapter on how deserts form takes us from 60 million years ago to the present day, with some salutary lessons around the effects of climate change. The rock art of the area is covered, as is the wealth of gems and minerals.

This photogenic country is captured in masses of colour photographs illustrating the features covered. A perfect companion on a trip across Namibia.

A LIFE IN BIRDS

Kingdom of Daylight: Memories of a Birdwatcher. By Peter Steyn. Peter Steyn. Cape Town. 2017

Peter Steyn is one of southern Africa's best-known birdwatchers and more than 70 years of birdwatching are celebrated in this fascinating book, filled with photographs. The author's passion for birds started early, his first bird photograph taken at the age of 13. In his introduction, Peter Steyn talks of the 'esctasy of birds and their sheer mastery of environments', which, as a birdwatcher myself, I can understand. This book takes us through not only years of birdwatching, but around the world. From a childhood in Cape Town, South Africa and Bulawayo in the then Southern Rhodesia, to the Antipodes, North and South America and the Indian Ocean Islands. Testament indeed to how an interest in nature – and in birds in particular – can lead you around the world.

The author's own photographs fill the pages, adding to his excellent text. An autobiography and nature book all in one.

NEW YORK CITY MICE EVOLVING TO EAT LEFTOVER FAST FOOD

A new preprint study published on bioRxiv (a place where scientists can publish research before submitting it to a journal) suggests that urban living is changing New York's mice, right down to their genes. Mice collected from around the city showed changes in their RNA in genes involved in digestion and metabolism compared with their country cousins. Among these genetic changes the scientists found one involved in the production of omega-3 and omega-6 fatty acids, similar to changes found in humans that arose around the time that our species changed from a hunter-gatherer lifestyle to one based on agriculture. These city mice showed signs of enlarged livers and genetic changes associated with non-alcoholic fatty liver disease, which may come from all the fast food in their diets. *Science News*

ANCIENT GENOME OFFERS CLUES TO OBESITY AND MORE

As researchers begin to identify the genes we have inherited from our long-extinct Neanderthal relatives, clues are emerging that may contribute to our understanding of cholesterol levels, the accumulation of belly fat and the risk of schizophrenia and other diseases. By sequencing a remarkably complete genome from a 50 000-year-old bone fragment of a female Neanderthal found in a cave in Croatia, scientists are reporting a mass of gene variants that people living outside Africa obtained from this species, many of which may still leave their mark. *Science News*

GIANT AUSTRALIAN STICK INSECT NOT EXTINCT

Scientists have confirmed that the giant insects found on rocks close to Lord Howe Island are a genetic match for the island's stick insects that were thought to have become extinct 100 years ago. The confusion arose because of major differences in the appearance of stick insects collected in the early 1900s and stored in museum collections, and those found in 2001 on Ball's Pyramid made people think that the latter was a related species and not the original. However, now, genome mapping of descendants of the Ball's Pyramid insects which were bred in captivity at Melbourne Zoo shows that these are indeed *Dryococelus australis*. The original 'extinction' was caused by black rats, which arrived on ships in 1918 and hunted the insects. Female Lord Howe Island stick insects grow to about 12 cm long, while males mature to just over 10 cm. They are not the largest stick insect in Australia – that honour goes to *Ctenomorpha gargantua*, which can grow to 50 cm – but their unlikely survival is a cause for celebration. *Science News*

Lord Howe Island stick insect (*Dryococelus australis*) at Melbourne Museum.
Wikimedia Commons

A honey bee carrying pollen back to the hive.
Wikimedia Commons

PESTICIDES FOUND IN HONEY AROUND THE WORLD

A new study has found that pesticides are present in honey samples from around the world, suggesting that bees and other pollinators are widely exposed to these chemicals. The commonly used insecticides, called neonicotinoids, are absorbed by plants and spread throughout their tissues. When pollinators collect and consume contaminated pollen and nectar, they can suffer health problems that can threaten the whole hive. The concern is the effect that this may have on the important role of honey bees and wild bees in pollinating crops, particularly fruits and vegetables. Samples have shown that the neonicotinoids are found in 86% of honey from North America, compared with samples from South America (57%). Globally, just over a third of samples had levels that have been shown to be dangerous to bees, although none of the samples had levels that are dangerous to human health.

Just one source of air pollution.
Pixabay

POLLUTION KILLED ONE IN SIX PEOPLE IN 2015

Dirty air, soil and water were to blame for the premature deaths of nearly 9 million people in 2015, according to a recent paper in the medical journal *The Lancet*. This is three times the number of deaths from AIDS, tuberculosis and malaria combined. In the most severely polluted countries, 25% of premature deaths could be put down to pollution, particularly air pollution. More than half of the global deaths from air pollution in 2015 were in China and India, according to the study.

This report, for the Lancet Commission on Pollution and Health, 'is the first time that it has all been brought together under one umbrella,' according to study co-author, Richar Fuller who is president of the NGO Pure Earth. About 90% of the world's urban population lives in cities where air quality does not meet World Health Organization standards. *The Lancet*

QUEST MATHS PUZZLE NO. 43

Which of these numbers is the odd-one-out?

43 26

50 37

17 82

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Tshwane University of Technology
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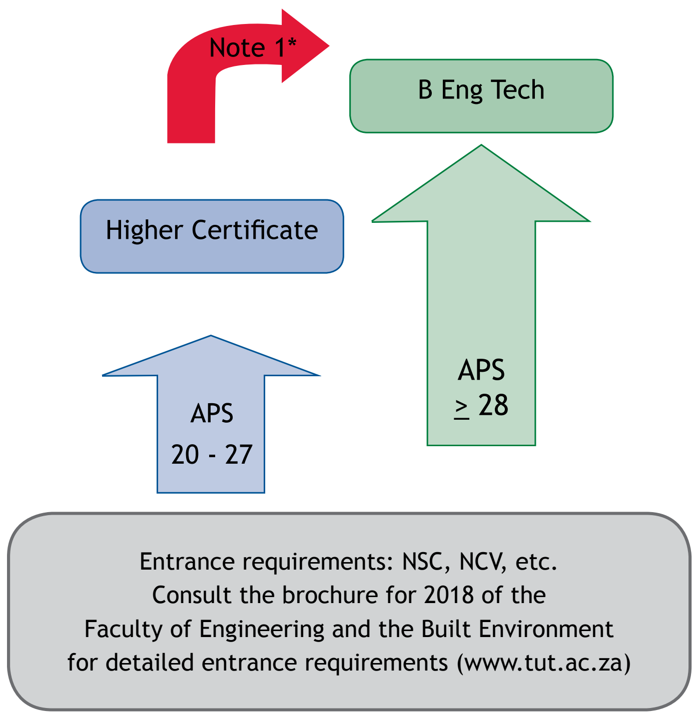
Faculty of Engineering and the Built Environment 2018 Qualifications

The introduction of the HEQSF in the Higher Education sector required all public and private Higher Education Institutions (HEIs), including Tshwane University of Technology (TUT), to revise all its qualifications to ensure alignment with the HEQSF.



***Note 1: Students who performed well in the Higher Certificate (HC) may be admitted into the B Eng Tech.**

The following new HEQSF aligned qualifications are presented from 2018:

- Higher Certificate in Construction Engineering (Civil)
- Higher Certificate in Industrial Engineering
- Higher Certificate in Mechanical Engineering
- Bachelor of Engineering Technology in Civil Engineering
- Bachelor of Engineering Technology in Electrical Engineering
- Bachelor of Engineering Technology in Industrial Engineering
- Bachelor of Engineering Technology in Mechanical Engineering
- Bachelor of Engineering Technology in Mechatronics
- Bachelor of Engineering Technology in Polymer

Admission requirements for the Higher Certificate in Engineering

A National Senior Certificate or an equivalent qualification, with at least a (4) for English, (4) for Mathematics and (4) for Physical Science. Total APS score: 24. This is the general requirement for the Faculty and it may differ for individual Higher Certificates programmes. This is a one-year qualification.

Admission requirements for the Bachelor of Engineering Technology (B Eng Tech)

A National Senior Certificate (NSC – completed Grade 12 in and after 2008), with an endorsement of a bachelor's degree or an equivalent qualification, with at least a *substantial achievement* of (5) for English, (5) for Mathematics and (5) for Physical Science. Total APS score: 28. This is a three-year qualification (integrated theory and practical).

The B Eng Tech meets the educational requirements for registration as a Professional Engineering Technologist with ECSA.

Departments of Building Sciences, Geomatics, Chemical Engineering, Metallurgical Engineering and Materials Engineering continue to present the current NATED151 qualification during 2018. The new HEQSF aligned qualification will start to phase in during 2019. Please consult the Prospectus of the Faculty of Engineering and the Built Environment (www.tut.ac.za) for more information.

Admission requirements for the Diploma in Building

A minimum score of (4) in English, (3) in Mathematics and (3) in Physical Science. Total APS score: 26. Admission is subject to available space.

Admission requirements for the Diploma in Industrial Design

A National Senior Certificate or an equivalent qualification with at least an adequate achievement of (4) for English. Total APS score: 21. In order to be considered for admission to this qualification, you must first meet the minimum academic requirements. All applications should be supplemented with a portfolio.

Admission requirements for the National Diploma: Surveying

A National Senior Certificate with an endorsement of a bachelor's degree or a diploma, or an equivalent qualification, with an achievement level of at least (4) for English (home language or first additional language), 4 for Mathematics/Technical Mathematics and (3) for Physical Science/Physical Science. A total APS of 23 may be considered

Admission requirements for the Bachelors of Architecture

A minimum score of (4) in English is required with a minimum APS score of 26. Admission is subject to the completion of a Potential Assessment Test (a 6 hour written test) and availability of space. The purpose and intention of the assessment is to select only students who are likely to be successful in their studies in Architecture. The University reserves the right to select the best candidates for this programme.

B Arch meets the educational requirements for registration as a Professional Architectural Technologist with SACAP.

Admission requirements for Postgraduate Qualifications

A Baccalaureus Technologiae in Engineering, Bachelor of Engineering Technology Honours, Bachelor of Engineering or a Bachelor of Science in Engineering (in any related field), or an NQF level 8 qualification in Engineering (or any related field), with an aggregate of 60 % for the final year of study obtained from an accredited South African university. The postgraduate programmes involve a research project with a dissertation and specified subjects. The candidates should prove that they understand a particular problem in industry to which their research applies and are able to analyse it, arrive at logical conclusions or a diagnosis and make proposals for improvement or elimination of the problems. Please consult the Prospectus available on the web site (www.tut.ac.za) for more information.

The Faculty phased in the Master of Engineering (M Eng) and Doctor of Engineering (D Eng) qualifications in 2017. The B Eng Tech (Hons) leads to a Masters of Engineering in Chemical, Civil, Electrical, Mechanical, Metallurgical and Polymer Technology. M Arch meets the educational requirements for registration as a Professional Architect with SACAP.

Visit the website at www.tut.ac.za

for detailed information on the various courses and access the Faculty of Engineering and the Built Environment page.

For more information:

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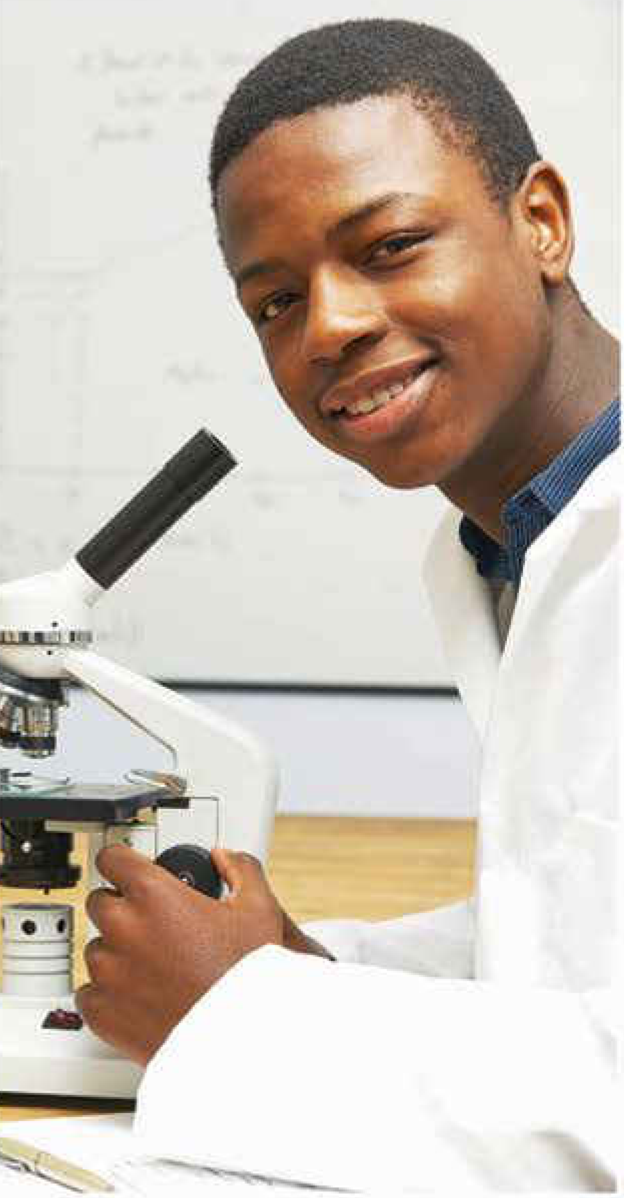

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