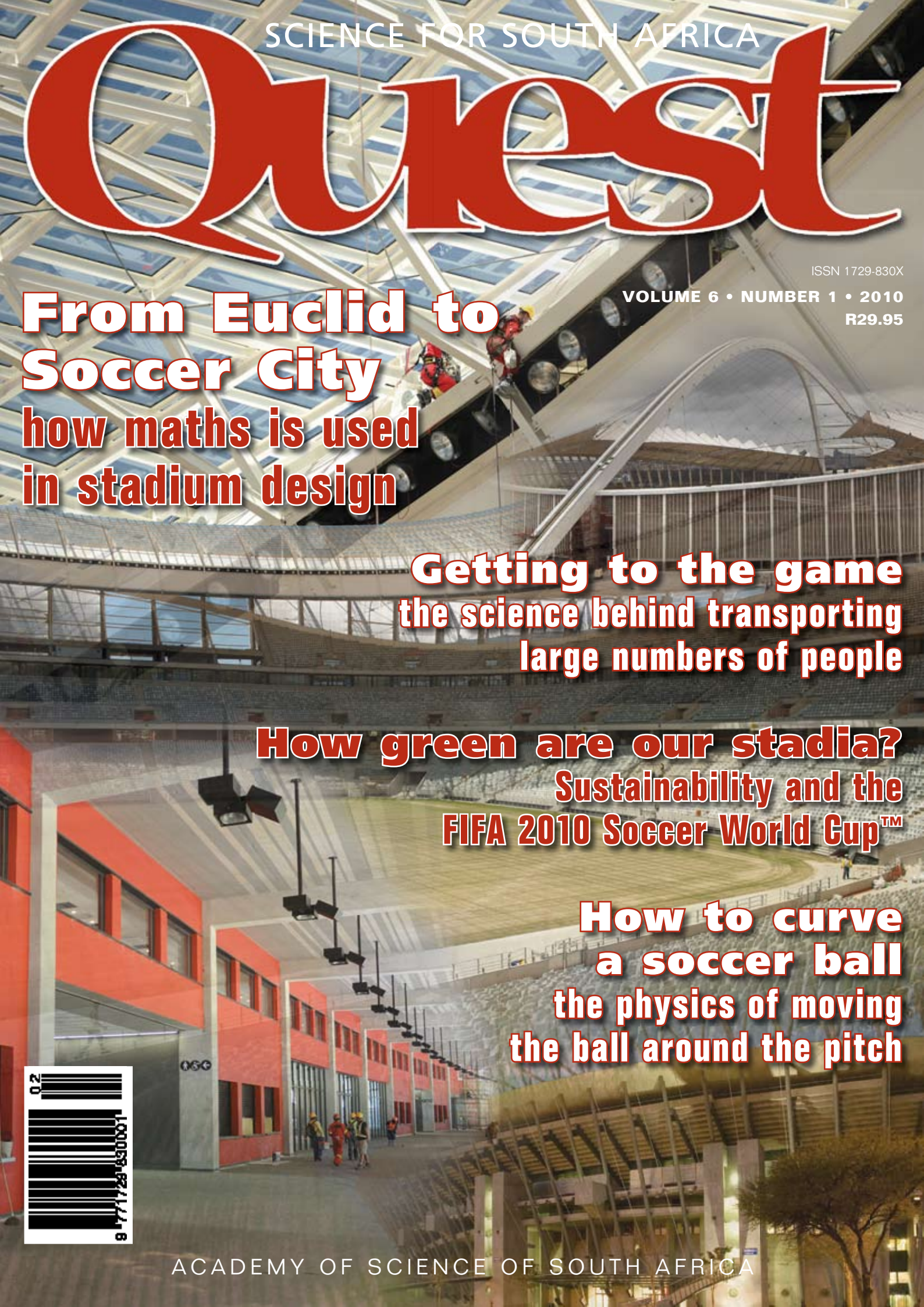

SCIENCE FOR SOUTH AFRICA

Quest

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From Euclid to Soccer City
how maths is used in stadium design

Getting to the game
the science behind transporting large numbers of people

How green are our stadia?
Sustainability and the FIFA 2010 Soccer World Cup™

How to curve a soccer ball
the physics of moving the ball around the pitch

ACADEMY OF SCIENCE OF SOUTH AFRICA

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The science of soccer. Images: PPC Cement, Darson Construction

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The beautiful game

Soccer is, quite rightly, called the 'beautiful game'. And anyone who enjoys the game and has had the pleasure of watching Premier League soccer will agree. It is a game of great athleticism and skill – and one that gives pleasure to countless millions around the world. It is probably the most popular sport globally – and is certainly the sport that arouses the most interest across Africa. The Premier League club Manchester United, for example, has tens of thousands of fans who probably have no idea where Manchester is! South Africa is, quite justifiably, proud to have been awarded the FIFA 2010 World Cup™ – and although the decision has drawn criticism from some quarters because of the costs involved, on balance I believe that hosting the tournament is positive for the region.

But soccer is more than simply an excellent sport. The science behind the game is myriad and fascinating. The game itself is subject to chance in a way that many other ball games are not – simply because it is low scoring. You seldom get games where the scores exceed two or three goals – whatever the skill of the two sides involved. And unlike many north American equivalents, the two halves of the game are long – making up a total of 90 minutes – which is a long time to be on a field of play. This means that the players must not only be skilled, they must be fit – a midfielder can easily run 10 km in the course of a match, a running distance that is generally regarded as an endurance distance, but which, because of the nature of the game, will also require sprinting. So injuries are common – and the tempation to enhance nature through pharmacological means is also there, making soccer subject to the scrutiny of the sport anti-doping agencies.

Then there is the ball itself – a perfect physics demonstration, as the best players manage to make it move fast and in different directions, particularly the bending that is required when taking a penalty kick. So far we have touched on mathematics and statistics, anatomy and medicine and physics.

But it is not just the players and the behaviour of the ball that is open to interpretation by looking at the science behind them. Soccer is played on a pitch – in most of Africa this is admittedly a dusty field somewhere with two goal posts at either end. But, at national and international level, soccer requires great stadia, which need engineers, architects, materials specialists and other scientists involved in the built environment, for their construction. Then there are town planners and transport experts who are required to make sure that the stadia are appropriate to their environment and that people can get to and from them comfortably and easily.

So, we have the beautiful game and the science of soccer. Enjoy the World Cup and take the positives from our ability to host the event – and also use this as an opportunity to learn something more about the science of our everyday world.

Bridget Farham
Editor – *QUEST: Science for South Africa*

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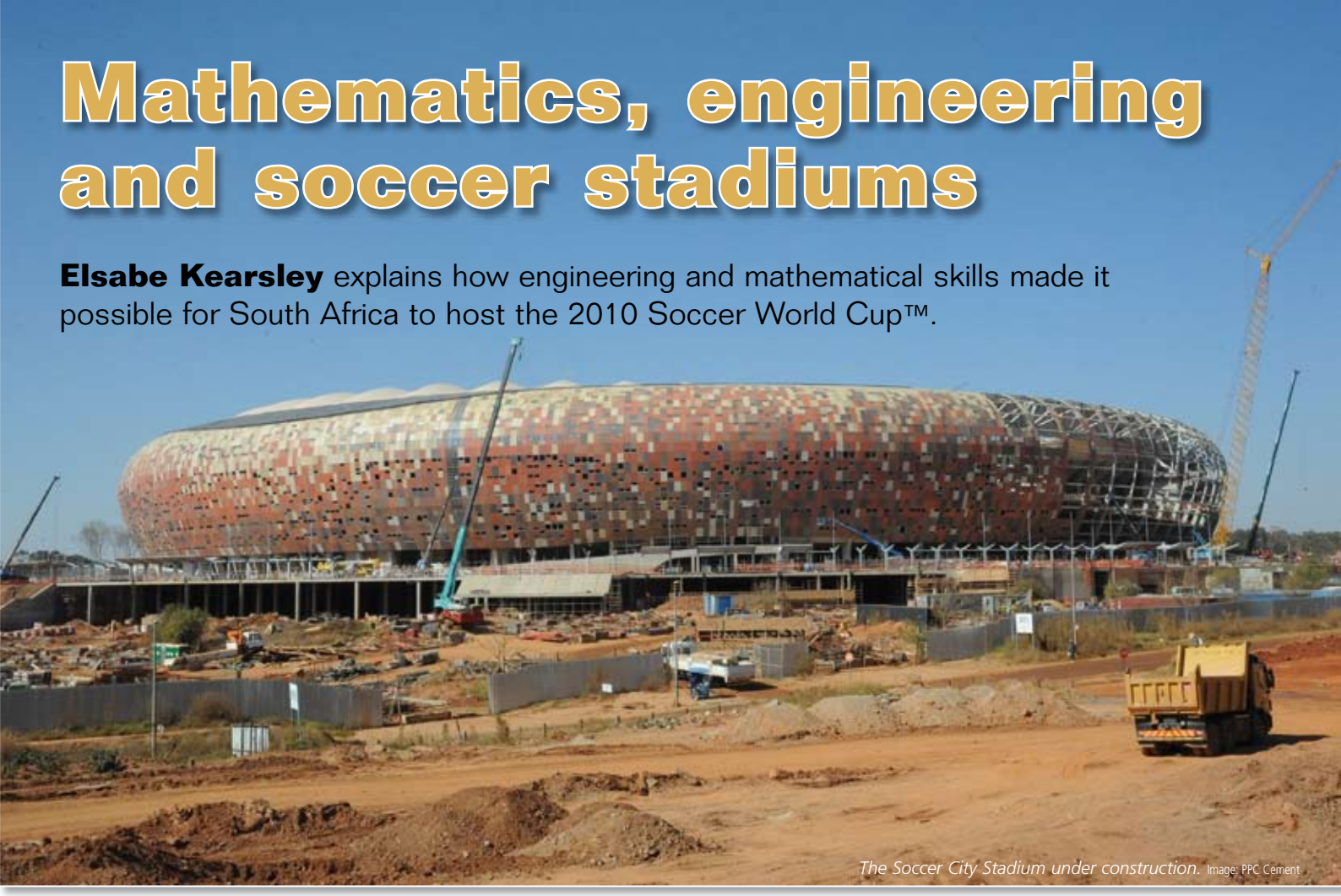
Mathematics, engineering and soccer stadiums

Elsabe Kearsley explains how engineering and mathematical skills made it possible for South Africa to host the 2010 Soccer World Cup™.



The Soccer City Stadium under construction. Image: PPC Cement

South Africa will be hosting the Soccer world Cup™ in 2010. In preparation for this event billions of rand have been spent on building new stadiums and upgrading existing structures.

Work on the nine stadiums (see the table) is nearing completion and as South Africans we can be proud of the world-class structures that will be used for all the soccer matches. It is worth pointing out that the Soccer City stadium can seat more spectators than any previous World Cup Soccer final venue!

Using mathematics

The civil engineering and construction industry have spent the last five years designing and building these facilities. All are built from steel and concrete, which is a combination of cement, water, sand and stone. During construction up to 2 870 people were employed to work on the Moses Mabhiba Stadium alone, while more than 2 500 people were working on the Soccer City site at the peak of construction activity. Every one of these people used numbers and mathematics in their daily activities.

The design concept used by the architects of the Soccer City Stadium was a calabash drinking bowl, an iconic symbol of African hospitality, sharing and companionship. The shape of this African pot made the design and construction of the structure very challenging as all the visible surfaces are sloping vertically and curve horizontally. The exterior finish of the stadium consists of 13 mm thick fibre-reinforced concrete panels with different earthy colours and surface finishes. These panels were placed in steel frames that are supported by 120 inclined concrete columns, some of which can be seen in the photo over the page.

The concrete columns are 16.3 m high and the top of each column has a horizontal eccentricity of 6.5 m in relation to the bottom. This means that the top of each column is 6.5 m further from the midpoint than the bottom of each colum.

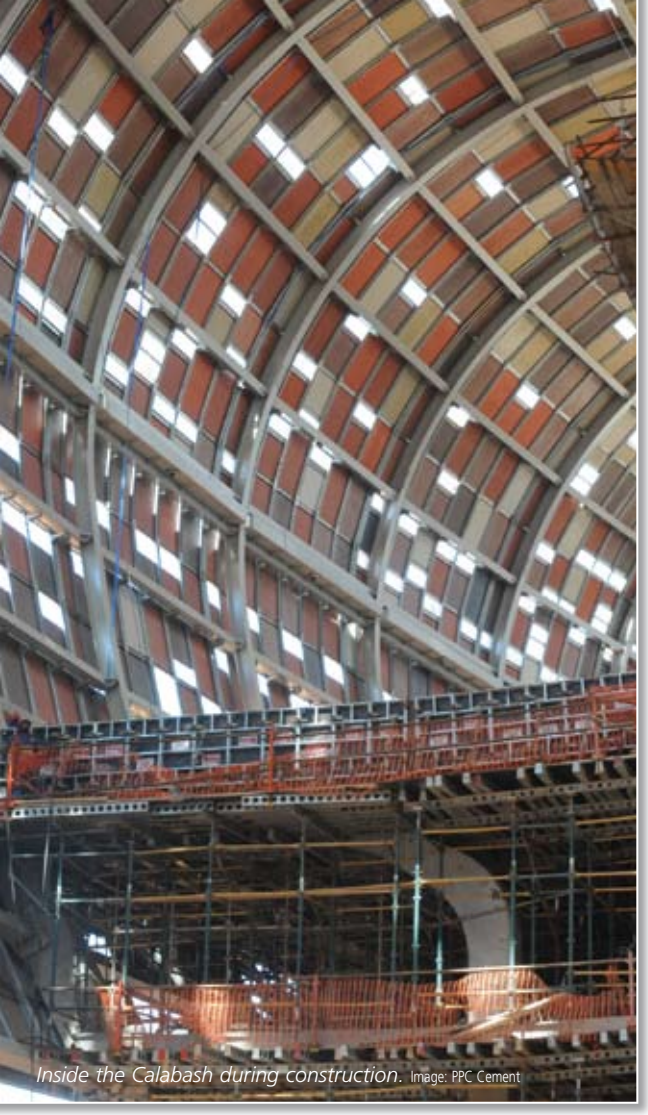
There is a 1 km long tension ring holding the top of these 120 columns in place.▷▷

Definitions

Accuracy: the degree to which a measurement represents the actual value of the dimensions being measured.
Precision: the accuracy with which a given measurement is taken.
Geometry: the branch of mathematics that deals with the properties and relationships between points, lines and surfaces.
Trigonometry: the branch of mathematics that deals with the relations of the sides and angles of triangles and the functions of those angles.

South Africa's soccers stadiums

Stadium	City	First Built	Current construction	Completion	Gross capacity
Green Point	Cape Town		new	2009	70 000
Moses Mabhida	Durban		new	2009	70 000
Soccer City	Johannesburg	1987	major upgrade	2009	94 700
Ellis Park	Johannesburg	1982	minor upgrade	2009	61 000
Free State	Mangaung/ Bloemfontein	1952	medium upgrade	2008	48 000
Port Elizabeth	Nelson Mandela Bay/Port Elizabeth		new	2009	48 000
Peter Mokaba	Polokwane		new	2010	46 000
Royal Bafokeng	Rustenburg	1999	minor upgrade	2010	42 000
Loftus Versfeld	Tshwane/ Pretoria	1906	upgrade	2008	50 000



Inside the Calabash during construction. Image: PPC Cement

Inside Soccer City where pre-cast elements were used in seating areas. Image: PPC Cement

The Moses Mabhida Stadium in Durban. Image: Darsan Construction

Sloping concrete columns at Soccer City. Image: PPC Cement

The concrete columns were cast in position on site. The contractor responsible for the construction of these columns had to ensure that they were built exactly according to the drawings because steel sections were manufactured to fit between the columns and if the dimensions of any the columns were incorrect it would have been impossible to fit the steel sections (seen between the concrete columns) in.

Timing was everything

To ensure that the stadium would be ready in time the process was speeded up by 'pre-casting' many of the concrete elements that were used inside the stadium. This pre-casting process ensured that all the pieces cast had exactly the same dimensions. Forms for the elements were manufactured and these manufactured moulds were used to cast concrete into the moulds. The pre-cast elements were then lifted into position using cranes as as shown in the photograph.

High school maths

Accuracy and precision are everything in the construction of structures such as the new and re-vamped soccer stadiums. The calculations and measurements of the forms used to make the concrete elements of the building use simple, high school geometry and trigonometry.

The Moses Mabhiba stadium in Durban was built on an old wetland swamp that was blanketed with sea sand in 1920 in order to eradicate malaria mosquitoes. The characteristic feature of the stadium is its 106 m high arch that stretches from one side to the other. A cable car that can carry 25 people will run along the arch from the north side to a viewing platform at the highest point of the arch. The southern side of the arch will contain 550 steps that climb to the same viewing platform.

The arch was built simultaneously from both ends. It consists of 56 steel pieces that were manufactured in Germany. Three pieces were shipped to Durban at a time. Each of the pieces weighed between 50 and 150 tonnes and the average size was 3.5 m x 4 m. The marquee-type roof of the stadium is suspended on the 102 cables that are tied to the arch. The contractors on site achieved the

The unique structure of the roof of the Port Elizabeth stadium.

high degree of accuracy that was needed to make sure that the last piece of the arch could be fitted in place.

The Port Elizabeth stadium has a unique eye-catching roof, which consists of a steel structure covered by a marquee-type roof which can be seen in the photograph.

Mountaineers were employed to fix the roof cover to the steel structure and they can also be seen climbing the structure in photograph.

Geometry, and what is called Euclidean geometry in particular, was essential to the successful construction of this complex structure. This means everyone, from the designer, the person who drew the plans to the welders and people erecting the structure, needed to have some understanding of these principles.

The calculations needed during the design and construction of the big soccer stadiums are all about space, shape and measurement including:

- Triangles, kites, parallelograms and rectangles
- Pythagoras' theorem
- Circles, tangents, arcs and chords.

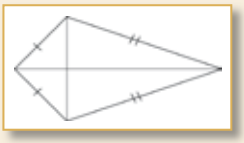
What about the pitch?

Once each of the stadiums is in place the pitch marking has to take place, but how do we know that the pitch as marked is rectangular? Again, geometry and trigonometry are essential. □

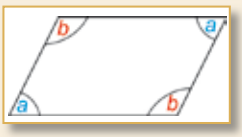
Elsabe Kearsley is Professor and Head of the Department of Civil Engineering at the University of Pretoria. She worked in Structural Design Engineering in both South Africa and the UK before becoming a staff member at the University of Pretoria. She was the 2009 President of the South African Institute of Civil Engineering (SAICE). For the last 15 years she has been involved with cement and concrete materials research and she has been an author of 42 peer-reviewed international conference and journal papers. Her research interests include promoting the use of lightweight and foamed concrete in infrastructure development.

Definitions

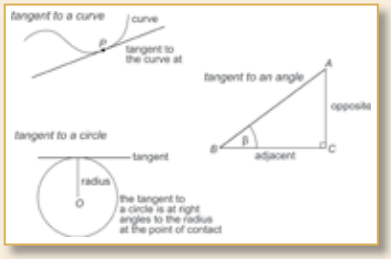
Kite: a four-sided figure (quadrilateral) with two pairs of equal sides.



Parallelogram: a four-sided figure with opposite sides equal in length and parallel to each other. Opposite angles are also equal.



Tangent: a mathematical function that is used in the study of right-angled triangles.

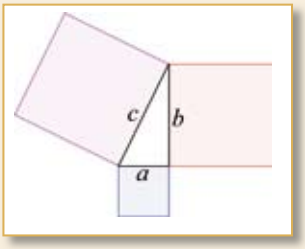


Chord: a chord is any straight line joining two points on a curve.

Euclidean geometry

Euclidean geometry is a mathematical system that was worked out by the Greek mathematician Euclid (330 bc). The system is based on a proposition that is generally thought of as self-evident, but that is not scientifically proven. Euclid's method then deduces many other propositions – called theorems in mathematics – from these.

One of the best known of Euclid's theorems is the theory of Pythagoras – in any right-angled triangle (a triangle that contains an angle of 90°) the area of the square on the hypotenuse (the side opposite the right angle) is equal to the sum of the squares of the other two sides.



Pythagoras' theorem: The sum of the areas of the two squares on the legs (a) and (b) of a right triangle equals the area of the square on the hypotenuse (c).

Roe access specialists involved in the construction of the roof of the Port Elizabeth stadium.

Association football pitch

An association football pitch is the playing surface for the game of association football. It is usually made of turf, although in many African countries this is not possible. Its dimensions and markings are defined by Law 1 of the Laws of the Game, 'The Field of Play'.

Since 2008, in order to standardise the size of the football pitch for international matches, the IFAB has set a fixed size of 105 m long and 68 m wide (instead of a minimum and maximum length – from 100 m to 110 m – and a minimum and a maximum width – from 64 m to 75 m).

All line markings on the pitch form part of the area that they define. For example, a ball on or above the touchline is still on the field of play; a ball on the line of the goal area is in the goal area; and a foul committed over the 16.5-m line has occurred in the penalty area. Therefore a ball must completely cross the touchline to be out of play, and a ball must wholly cross the goal line (between the goal posts) before a goal is scored; if any part of the ball is still on or above the line, the ball is still in play.

A football pitch showing metric and imperial measurements. Imperial measurements are still used in countries such as Britain and the USA.

West entrance view, with bridge. Image: SAICE

South African team takes top honours at steel awards

An all South African team of main contractor, architects, structural engineers, quantity surveyors and project manager recently took the category award for technical excellence at the prestigious South African Institute of Steel Construction's annual awards ceremony.

The project in question was the R340 million refurbishment of the Royal Bafokeng Sports Palace outside Rustenburg, on behalf of the Royal Bafokeng Administration.

The unusual design and technical brilliance of this project prompted the judges to remark, 'It is perhaps the simplest design to the untrained mind by its apparent neat appearance. But the project displays some amazing technology in design and execution, with lots of firsts when compared with other stadia'.

The upgrade saw the stands on the western side of the stadium increased in capacity, bringing the total ground capacity up from 39 000 to 45 000. M² Consulting Engineering (now incorporated into Vela VKE Consulting Engineers), who were involved in the original stadium design, were asked to design the upgraded structure.

Says Marius Mostert, MD of M² Consulting Engineering, 'The timeframe was extremely tight for the concept and preliminary design. The detailed design took approximately one year and we achieved practical completion the day before the first game was played on March 28th this year'.

The design concept had to take into account the precision required to calculate the angles of the bracings that connect into the nodes (or 'knuckles') around the elliptically shaped stadium, which vary in each of the 32 bays. The bracings support the steel structure for the roof, which leads up to a high point in the centre and slopes down to the outer ends.

'The erection process was extremely difficult and involved a scaffold platform up to 33 m high. The setting out, site welding, concrete infill in the members and stressing of the roof hangers were a major challenge for all disciplines involved', explained Marius Mostert.

From a sustainability point of view it is always preferable to source all material and resources as close to the project as possible. This was achieved with the design, fabrication, erection, stressing and sheeting used in this project. The only item that was imported was the translucent polycarbonate sheeting on the tip of the roof.

The major team effort by all parties involved in this project has resulted in an extremely high level of workmanship, including such attention to detail as the internal shear studs being laid out in an identical pattern on each external column. □

Main roof showing structural details. Image: SAICE

Getting to the match

Mathetha Mokonyama and **Bongi Mpondo** discuss the science of transporting large crowds of people, vital to a successful 2010 FIFA World Cup™

The already congested transport networks in many South African cities, including roadways and public transport services, will need to cater for additional and unprecedented large numbers of travellers during the 2010 FIFA World Cup™. Many South Africans are justifiably sceptical about the ability of the country's transport system to cope adequately with the additional requirements imposed by the soccer tournament.

This lack of confidence is reinforced by their recent experiences during the 2009 FIFA Confederations Cup, where the performance of the transport sector was rated poorly by FIFA, following numerous complaints from match spectators as well as scathing media reports. These complaints included excessively long queues at public transport waiting facilities that led to late arrivals at stadiums, poor information for spectators, public transport drivers getting lost, and poor coordination between match and flight schedules.

The performance of the transport sector is indeed critical for the successful hosting of the World Cup, implying that if the transport system fails, it will not only fail the spectators, but also leave an unpleasant aftertaste for future international visitors.

The 2010 FIFA World Cup™: unique in many respects

The 2010 World Cup is unique in many respects. South Africa does already host large events from time to time, such as the religious pilgrimage of the Zion Christian Church near Polokwane, funerals of famous people, music festivals, numerous other sporting events, and political rallies. However, the World Cup will take place concurrently in many parts of the country, it involves large numbers of both local and international travellers, it is associated with huge financial investments from large brands, and inherently attracts intensive international attention. In response to this challenge, South African host cities, as well as other government bodies, have prepared detailed transport plans for the event.

Planning for the match

For large sporting events, transport and traffic engineers as well as town and regional planners are mainly responsible for planning transport systems for implementation by other professionals such as the police and event managers. In order to systematically design a transport plan for the event, it is important to understand concepts such as static and dynamic infrastructure capacity, as well as the role of spatial distribution of land use.

Agitated passengers waiting desperately at night for buses destined for park-and-ride facilities to arrive after a match in Johannesburg.

Sociology is the study of human societies.

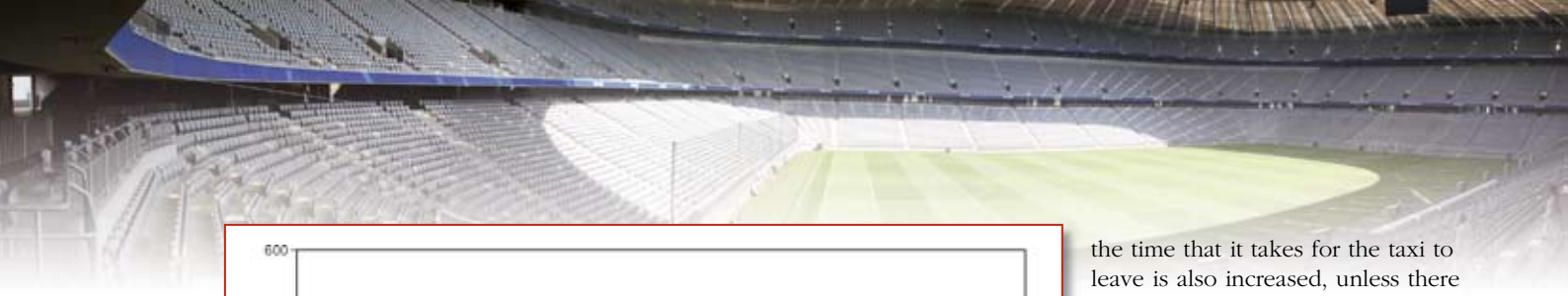
It also helps when the planners have some knowledge of sociology in order to understand the multitude of different travel needs of different groups in society. For example, the elderly, disabled people, cultural differences in approach to transport and varying cognitive abilities. Very important in the planning process, however, is to ensure that the budget required to implement the recommended solution is minimised. As the old saying goes: 'The difference between an engineer and a lay person is that, while both can solve the same problem, the engineer can solve and implement it at ten times less costs than the lay person'.

Why is infrastructure important?

The *static* capacity of transport infrastructure refers the maximum number of people or vehicles that can be accommodated at any given time. An example is the total number of parking bays for vehicles or the total number of spaces that can safely be occupied by passengers in a vehicle. Planners need to make sure that the number of vehicles or people does not exceed the available static capacity. In order to maximise infrastructure capacity for large events, it is considered best practice to plan on the basis of maximising capacity for the numbers of people rather than the numbers of vehicles. People occupy less space than vehicles, so limited space can be used more productively.

This is the reason that host cities want people who are going to the matches to use public transport as much as possible in order to maximise the total number of people per vehicle. Where vehicles have to be parked, it is advisable to have multistorey parking facilities in order to minimise the amount of land needed for parking. Furthermore, when car parking is concentrated in one multistorey building, it makes it easier to define and fix where people get onto and off public transport where a park-and-ride concept is used.

One of the errors made during the 2009 Confederations Cup was to rely largely on single storey-parking ▹▹



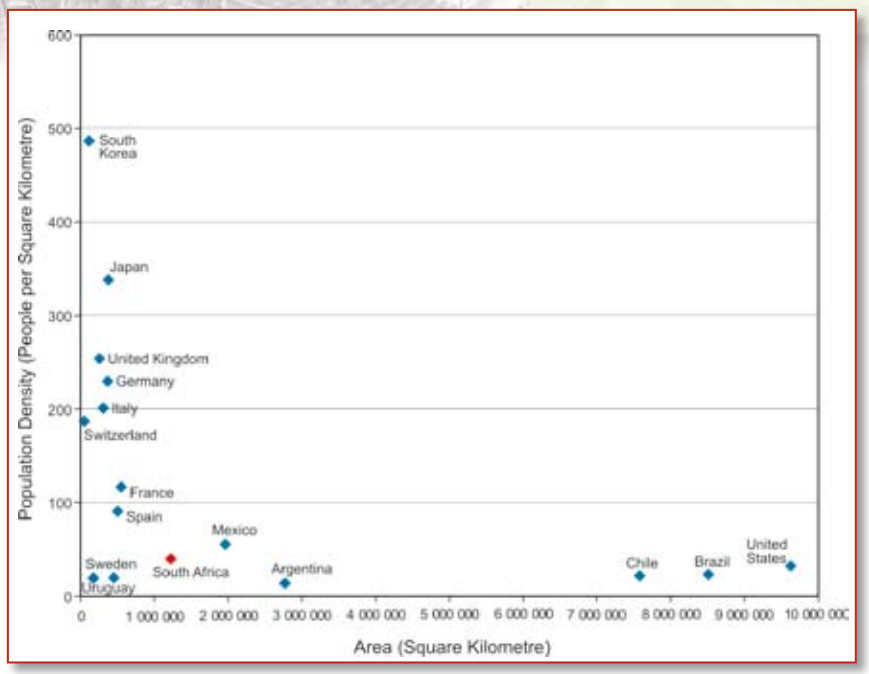


Figure 1: Population densities and surface areas of countries that have hosted the FIFA World Cup.

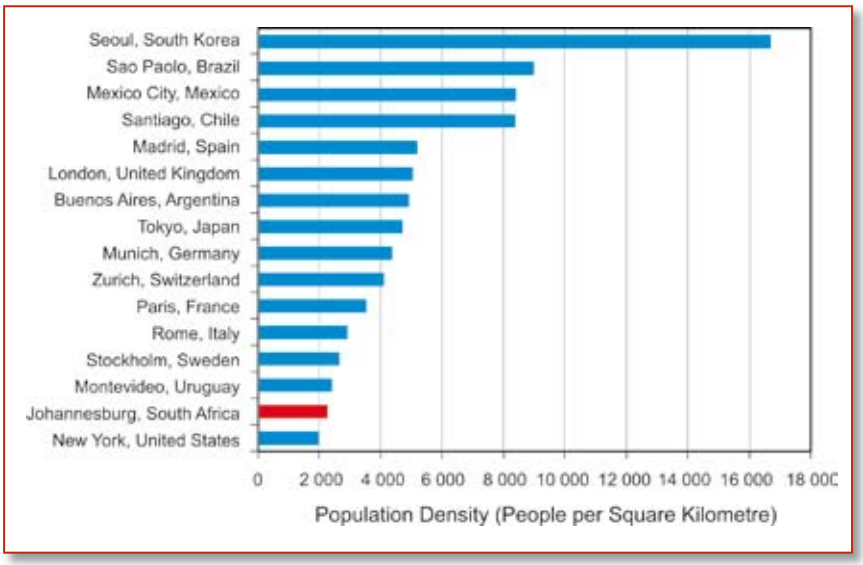


Figure 2: Population densities of selected cities in countries that have hosted the FIFA World Cup.

facilities. For the 2010 World Cup the best plan would be for host cities to negotiate the use of parking spaces with owners of multistorey parking facilities.

While static infrastructure capacity is relatively straightforward to manage, *dynamic* capacity is often neglected to the detriment of the entire plan. It is when dynamic infrastructure capacity is exceeded that symptoms of failure, such as very long queues, happen.

For public transport routes, it is important to plan the elapsed time between successive vehicles (called the vehicle headways) to match the expected number of people on the route, as well as the rate at which they will arrive. However, very short headways translate into a requirement for large numbers of vehicles, especially for longer routes. This in turn results in large budget requirements. This in turn leads to the idea of transport networks rather than isolated routes. When properly designed, networks allow a given number of vehicles to serve more people than would be the case with isolated routes.

The size of vehicles is also important. Smaller public transport vehicles such as minibus taxis lead to longer queues than larger vehicles such as buses, because it takes longer for each passenger to board and then the time that it takes for the taxi to leave is also increased, unless there are a lot of taxis available at the same time.

Larger vehicles need more doors so that the maximim number of people can enter or leave the vehicle per unit time. A large vehicle with long cabins may be more efficient if there are separate entry and exit doors. When passengers have to pay fares, the servicing rate needs to maximised in order to reduce long queues. The prepaid fare system used for the Bus Rapid Transit system buses in Johannesburg, for example, allows people to board faster than they could if they were paying a driver.

Planners also need to know in advance the servicing capacity of toll gates on tolled roads, airline ticket sale booths and border posts. The anticipated numbers of people travelling to and from stadiums mean that World Cup travellers should get right of way at potential bottle necks.

Spatial planning

In South Africa nine cities will be hosting the World Cup. This is in contrast to the 2006 World Cup in Germany, where 12 cities hosted the event. Germany was able to afford to host the tournament in many cities partly because of the spatial configuration of the country as well as its supporting high-capacity transport network. Figure 1 shows the relationship between the surface area and population densities of all the countries that have previously hosted the FIFA World Cup.

Germany has a higher concentration of people in a smaller surface area relative to South Africa. The extreme case is South Korea. In small areas that are highly populated, it is cheaper to provide public transport. For example, in denser cities accommodation for tourists is located in areas that can be served by a smaller public transport network, requiring relatively fewer resources.

There are, however, countries such as the United States and Chile with larger surface areas than South Africa that have successfully hosted the FIFA World Cup. Nonetheless, as Figure 2 shows, many of these countries have cities that are more densely populated than a typical South African city. Figure 2 shows the density in the entire metropolitan area, and therefore the density of central Johannesburg is

likely to rank lower that the density of central areas in the identified cities. Fragmented land usage in South Africa will create challenges in transporting people around the country, and even within cities, during the 2010 World Cup.

Planning

Several other planning considerations such as information dissemination are also critical. When designing a map, for example, it is important to ensure that people can use it. There are some best-practice cartographic standards that need to be implemented when designing maps to ensure that they are effectively used. According to these standards, for example, when providing the map on-line for internet users, it is important to make sure that if it is printed in black and white the spatial features are legible. It is also important to superimpose tourist facilities on the public transport network.

Planning for potential disruptions such as electric power outages and unfavourable weather conditions is equally important. Power outages can affect the use of rail lines and traffic lights, and therefore city authorites may need standby fleets of buses or diesel-operated trains. Weather can reduce the capacity of the transport system, for example water pooling in parking facilities, something that is highly likely to occur in Cape Town with its known winter rains.

In conclusion

Despite the many challenges and solutions to providing an efficient transport system for World Cup visitors, the inherent ability of people to 'make a plan' needs to be taken into consideration. People will always devise their own survival plans, which are sometimes much better than the solutions provided by engineers and scientists, further showing that there is an engineer or scientist in all of us. □

Mathetha Mokonyama is a transport engineer at the CSIR, and Bongi Mpondo is a town and regional planner and the Managing Director of Safiri (Pty) Ltd. They have both provided independent advice to the national department of transport in respect of transport planning and implementation for the 2010 FIFA World Cup™.

Cartography: the science of map making

Cartography is the study of and practice of making geographical maps.

One of the oldest known maps is a nautical chart of part of the Mediterranean sea.

The main things that a cartographer (a map maker) needs to be aware of are:

- What the map will be used for and how to select the characteristic of the area to be mapped
- To represent the terrain of the area as flat
- Eliminate characteristics of the mapped area that are not relevant to the map's purpose
- Make the map as simple as possible without removing the characteristics that will allow the map to be used easily.

One of the oldest known maps. Image: Wikimedia

Science news

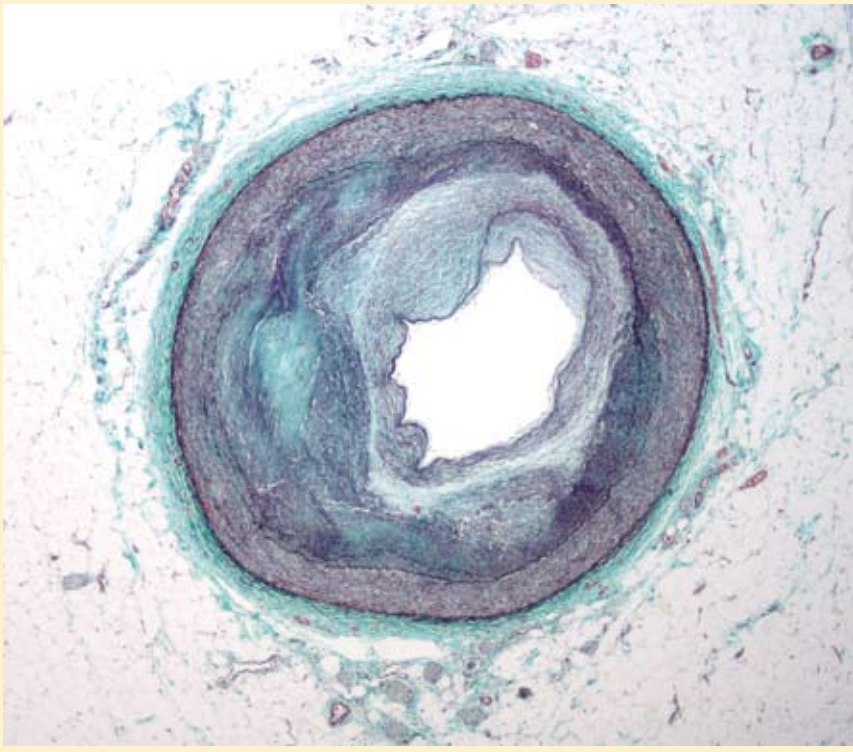
Risk of developing heart disease linked to junk DNA

So-called junk DNA is the 98% of our genome that apparently does not code for proteins. However, it is probably not simply 'junk', as researchers are starting to realise. Scientists have recently found that at least one section of it possibly raises the risk of one form of heart disease in some people.

In a study in 2007, scientists linked a non-coding stretch of chromosome 9p21 with coronary artery disease – the disease that leads to narrowing of the arteries of the heart, heart attacks and death. They showed that people who carry certain mutations in this part of the chromosome had a higher risk of developing coronary artery disease.

Now, in a study published online in *Nature*, researchers have reinforced the finding by actually deleting the equivalent area of this chromosome in mice. Taking away this non-coding area had definite effects on other parts of the chromosome, which did carry genes that coded for proteins – and the mice with the deleted non-coding DNA died earlier than normal and some developed tumours. The finding that raised the possibility of the non-coding section being related to an increased risk of heart disease, however, was that mice without this non-coding section of DNA showed increased muscle growth in the aorta – the largest artery in the body – which could potentially block blood supply.

The researchers are not yet sure how this relates to humans, but, taken along with the earlier finding of the link between mutations and risk, this finding may lead to further information about exactly what it is that predisposes certain people to heart disease. Source: Visel, A. et al. Nature advance online publication doi: 10.1038/nature08801 (2010)



A micrograph of a coronary artery showing the most common form of coronary artery disease with marked narrowing of the lumen of the artery. Image: Wikimedia

Green Point stadium, Cape Town, under construction. Image: CSIR

QUEST spoke to researchers in the built environment to find out how we are ensuring that the 2010 FIFA World Cup™ stadia meet green goals.

Sustainability key to the future of our soccer stadia

In June and July 2010 South Africa is host to Africa's first Fédération Internationale de Football Association (FIFA) World Cup™. Since we were awarded the World Cup in May 2004 ten soccer stadiums around the country have undergone an extensive process of rebuilding and refurbishment, and in some cases total reconstruction.

Although we have generally excellent infrastructure, South Africa is a country in which there is still an enormous social divide, as is the case on the rest of the continent. As a result, the government, through the Department of Environmental Affairs and Tourism (DEAT), as part of South Africa's bid campaign, promised that hosting the World Cup would ensure 'a lasting social legacy through the event and leverage the event to spread economic and social benefits beyond the borders of South Africa.'

The Green Goal initiative

This process is not without its impacts – the main one being on the environment around the stadia. The 2006 FIFA Soccer World Cup™ was held in Germany – a country with far more resources than South Africa – and it was the preparations for this event that lead to the development of the Green Goal™ initiative. The Green Goal™ is simple – the environmental impact of the events associated with the World Cup should be minimised as far as possible. However, as previously stated, in South Africa we need to consider more than just the environmental costs.

The Sustainable Building Assessment Tool (SBAT) was developed to provide a framework for the development of the built environment in a developing country such as South Africa. The tool is based on international best practice in the industry and has been modified and refined to reflect the South African situation. The project started in July 2007 and was undertaken by Green by Design (GbD), Paul Carew Consulting (PjC) and the South African Council for Scientific and Industrial Research (CSIR).

The Sustainable Building Assessment Tool (SBAT)

The SBAT was developed to provide a framework for the development of the built environment in a developing country such as South Africa. The tool is based on international best practice in the industry and has been modified and refined to reflect the South African situation.

There are five criteria in all three sustainability areas:

- Economic – local economy, efficiency, adaptability and flexibility, ongoing costs and capital costs
- Environmental – water, energy, waste, site, materials and components
- Social – occupant comfort, inclusive environments, access to facilities, participation and control, education, health and safety

This provides a solid framework that is used to assess the sustainability performance of proposed designs and existing buildings.

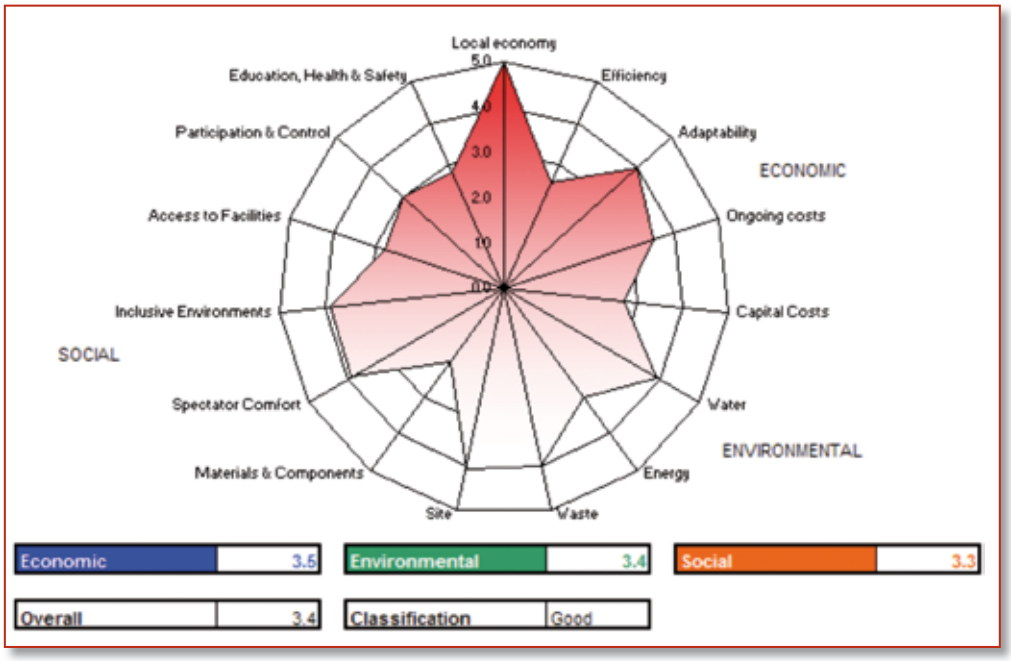
Jeremy Gibberd and Nosizo Sebake from the Council for Scientific and Industrial Research (CSIR) Built Environment Unit, modified the original SBAT tool so that it could be used specifically for stadia.

How is SBAT for Stadia used?

The tool was developed after stadium construction had started, so had little impact on stadium design. The two CSIR researchers, did, however, examine other aspects of sustainability, in particular the social and economic concerns, as well as environmental ones.

The radar diagram shows how the various criteria used in SBAT for Stadia can provide an appraisal of the sustainability of a specific stadium.

The SBAT report in the diagram indicates that the overall sustainability performance of the sample stadium is good and fairly well balanced across the three different sustainability areas. Relatively poorly performing areas



A sample SBAT report presented as a radar diagram.

include efficiency, capital costs and materials and components, which rated just under a score of 3 (*Average*). Areas that appear to perform well include the local economy, adaptability and site and rated well over 3 (*Good* to *Very Good*).

The overall rating of 3.4 (*Good*) indicates that the approach taken is robust and may lead to a *Very Good* sustainability performance through the adoption of sustainable technology and management techniques. The balanced performance (ratings vary from 3.3 to 3.5) within the three sustainability areas shows that there has been an even and effective handling of the performance objectives and that one area (such as environmental issues) has not been allowed to eclipse the others. This balance is likely to have been achieved as a result of the experience of the professional team, the procurement policy and other policies being applied to the project.

How has SBAT for Stadia been applied?

Among the ten stadia that were either constructed or restored for the World Cup, five participated in a SBAT for Stadia review. In all five cases the South African Department of Environmental Affairs, through the Urban Environmental Management Programme (UEMP), which is commissioned by the Royal Danish Embassy, commissioned a review of the greening status of the official FIFA World Cup™ training and match stadia. This not only established how green the stadium designs were, but also gave the design teams the opportunity to enhance some of the green aspects of their design.

Athlone stadium

Athlone stadium, in Cape Town, is an interesting example of the use of SBAT for Stadia. The stadium was not refurbished for matches, but as a 'fan park' and for training. But this did not stop the contractors from looking at the sustainability of the project, particularly as this stadium is in one of the less affluent areas of Cape Town.

The plan was to increase the stadium's capacity to 30 000 under-roof seats. A review of the sustainability of the project, using SBAT for Stadia only started after the refurbishment, which had already started in 2008. So the sustainability review team realised that large-scale interventions would not be possible. However, smaller interventions and improvements in management of the facilities could still play a major role in the 'greening' of the stadium.

The key issues that they identified included training and incentives for facilities-management staff and construction workers, monitoring the stadium's social and economic impact, specifically the local economy, and improving the quality and security of pedestrian access and paths.

Specific interventions

One of the main interventions at Athlone stadium was in terms of water consumption, which was minimised through a number of interventions:

- Dual-flush toilets in VIP facilities
- Only the pitch is irrigated
- No additional landscaping
- Most hand-wash basins in public facilities supplied with cold water only
- Stadium design allowing for the installation of water meters without having to redo the plumbing. ▷▷

Athlone stadium under construction. Image: CSIR

The arch over Athlone stadium. Image: CSIR

The World Cup's carbon footprint

The estimated carbon footprint for this year's World Cup, excluding international travel, is 896 661 tonnes of carbon dioxide equivalent (tCO_2e). This is eight times greater than the last World Cup in Germany.

When international travel is included, the number rises to 2.75 million tCO_2e, making it one of the biggest sports events by carbon emission.

Can this be offset? Offsetting is expensive and will depend on the amount of money that the organisers can raise. Offsetting only the domestic carbon footprint could cost between $5.4 million and $9 million (R41 million and R69 million).

The new dual flush toilets. Image: CSIR

Energy efficiency was another important area. Energy-efficient features that were being considered, or which had already been implemented, include:

- As an open stadium, ventilation is natural (wind-driven) while natural light penetrates the stands.
- Different floodlighting levels for training and actual matches.
- A generator is hired to power the floodlights during matches.
- As hot water is sourced from individual geysers, water heating could be isolated or timed. Geysers only need to be switched on when and where they are needed.
- Hot water is not provided for spectators' ablutions.
- Compact fluorescent light bulbs should be fitted in all internal spaces.
- Feature lighting is linked to a timer or light sensor.
- The stadium is wired to facilitate load shedding. Geysers and non-essential lighting circuits can be switched off if the load reaches maximum capacity.
- The large roof expanse could be exploited for a photovoltaic installation.

In other interventions it was suggested that waste generated by the refurbishment should be documented before being sent to landfill sites, in an effort to keep this to a minimum and that waste collected in the stadium itself be separated for recycling. Public transport to the stadium would be encouraged, with an upgrade to the nearby rail station, as well as the introduction to 'park-and-ride' facilities.

The triple bottom line

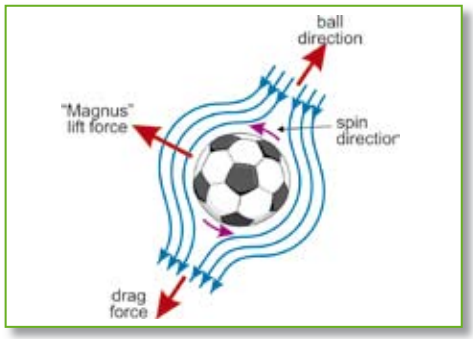
Unlike the World Cup in Germany, where the focus was exclusively on environmental issues, the performance of the Athlone stadium was measured in relation to social, economic as well as environmental criteria. And it was in terms of the local economy and spectator comfort that Athlone scored. The refurbishment of the stadium was carried out using local labour, local building materials, local components and fittings, local furniture and maintenance will be carried out by locals. The stadium has also been developed in a way that allows alternative uses, important when the World Cup is over.

Similar sustainability studies have been carried out on Moses Mabhida stadium, Durban, Green Point stadium, Cape Town, Royal Bafokeng stadium, Rustenburg and Peter Mokaba stadium, Polokwane.

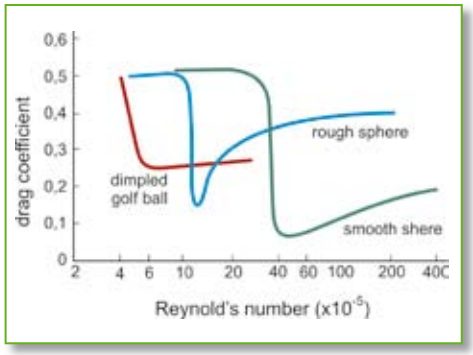
Green Point stadium was also assessed as being in line with the City of Cape Town's policy of procuring services from small businesses and historically disadvantaged individuals and use of local resources. For example, the project provided local employment. Green Point stadium is surrounded by a multi-functional urban park, replacing a previously unattractive and under-used area of the city. Being a big match stadium, particular attention was also paid to spectator comfort and access by disabled people. There are transport facilities within 400 m of the stadium, lifts to all levels of the stadium and toilets no more than 50 m from seating. The stadium is also close to accommodation. □

How to curve a soccer ball

QUEST finds out how soccer players can 'bend it like Beckham'.



A bird's-eye view of a football spinning about an axis perpendicular to the flow of air across it.



The drag coefficient of a ball plotted against Reynold's number – a non-dimensional parameter that takes into account both the velocity and diameter of the ball.

It has been said that 'soccer is not about life and death, it is more important than that'! Soccer is probably the most popular sport in the world and one of its attractions is the apparent unpredictability of ball motion – making goalkeeping spectacularly difficult – and spectacularly impressive when a ball is kept out.

It is not simply the skill of the players that is behind this feature of soccer, although that is vital, but how they use the physics behind the movement of the ball to their advantage. And how to curve the ball is paramount, particularly in free kicks.

Aerodynamics and sports balls

Bending, or more correctly, lateral deflection, of a spinning object was first investigated by the German physicist Gustav Magnus in 1852. His work was on spinning shells and bullets, but the physics is equally applicable to balls – and in any sport, not just soccer.

To look at how a ball spins you need to look at it using the laws of physics.

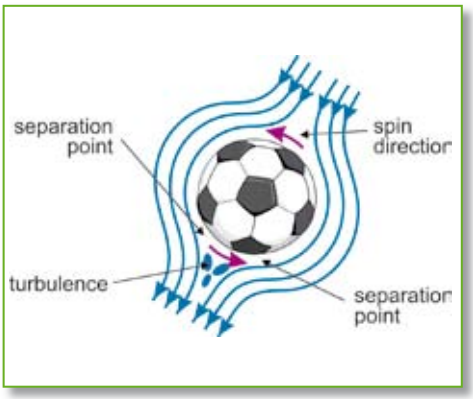
Look at a ball that is spinning about an axis that is perpendicular to the air that flows across it. The air travels faster relative to the centre of the ball where the periphery of the ball is moving in the same direction as the airflow (left). This reduces the pressure, according to Bernoulli's principle. The pressure increases on the other side of the ball, where the air travels slower relative to the centre of the ball (right). There is therefore an imbalance in the forces, and the ball deflects in the same sense as the spin – from bottom right to top left. This lateral deflection of the ball in flight is called the Magnus effect.

Bernoulli's principle: this principle states that an increase in the speed of a fluid produces a decrease in pressure and a decrease in speed produces an increase in pressure. Air behaves like a fluid.

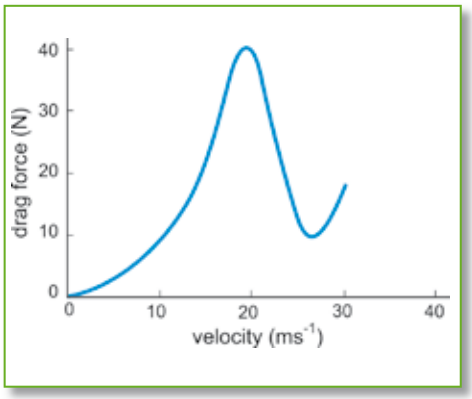
There are two types of forces that affect a spinning ball as it flies through the air. These forces are lift force and drag force. The lift force is the upwards or sideways force that is responsible for the lateral deflection (the Magnus effect). The drag force acts in the opposite direction to the path that the ball is taking.

A free kick

Using all this physics it is possible to calculate the forces on a soccer ball during, for example, a free kick. If you assume that the soccer player has kicked the ball at a velocity of 25-30 metres/second (m/s),



When the airflow over a ball is turbulent, the boundary layer sticks to the ball almost until the air has completely passed over the ball. This produces late separation and a small drag.



The variation of drag force with ball speed. At high speeds, the drag force falls, which means that the ball does not slow down as much as expected.

which is about 112 kilometres per hour, and that the spin on the ball is about 8-10 revolutions per second, then the lift force is about 3.5 N.

N: a newton, the unit of measurement of forces. It is defined as the force that gives a mass of 1 kg an acceleration of 1 m/s.

A professional soccer ball must have a mass of 410-450 g, which means that it would accelerate by about 8 m/s. The ball would be in the air for 1 s of its 30 m flight path or trajectory and so would be able to deviate by as much as 4 m from its original straight line course. Quite a deflection to deal with as a goalkeeper!

What a drag

As the ball moves through the air faster so the drag force on it increases – as a square of the ball's velocity. But, air turbulence complicates this relationship. Something called the drag coefficient also depends on the velocity of the ball. The drag coefficient is a quantity (without any dimensions) that is used to quantify the drag or resistance of an object in a fluid such as air or water.

Now we need to look at the relationship between the drag coefficient and something called Reynold's number. Reynold's number is another dimensionless number that provides a measure of the relative importance of drag and lift, in this case on the soccer ball as it flies through the air.

If you look at the graph you will see that the drag coefficient drops suddenly as the flow of air over the ball becomes turbulent.

The Reynold's number that causes this drop in drag coefficient depends on how rough the surface of the ball is. A soccer ball is relatively smooth, which means that if the ball moves slowly initially it will slow down much faster during its flight than it would do if it had moved faster in the first place.

What this means during a soccer game is that if the player can kick the ball hard enough and fast enough it will slow down much less than expected during its flight – double trouble for the goalkeeper – who has a fast, unpredictable ball to deal with.

We also know from experiments done in the 1970s that a slow-moving soccer ball with a lot of spin will have a larger sideways force than a fast-moving ball with the same spin. So, as the ball slows down at the end of its flight, the curve becomes more pronounced.

Bend it like Beckham

So, when David Beckham takes a free kick and really bends the ball this is probably what happens.

First he makes sure that he spins the ball, probably at more than 10 revolutions per second. If he kicks it with the outside of his foot he can hit it hard – at more than 30 m/s. The flow of air over the ball will be turbulent, giving it a relatively low drag. As the ball flies through the air its velocity drops, probably around the 10 m mark, and it enters a less turbulent or laminar air flow, which increases the drag on the ball, which makes it slow down even more. This allows the sideways Magnus force, which is bending the ball towards the goal, to come into play. If the spin has not decreased too much, the drag coefficient increases, which produces an even larger sideways force and the ball can bend even further. Finally, as the ball slows, the bend becomes even more pronounced and hits the back of the net! Laduma! □

The mathematics of soccer

Mathematician **Steve Sherman** looks at how the statistics add up.

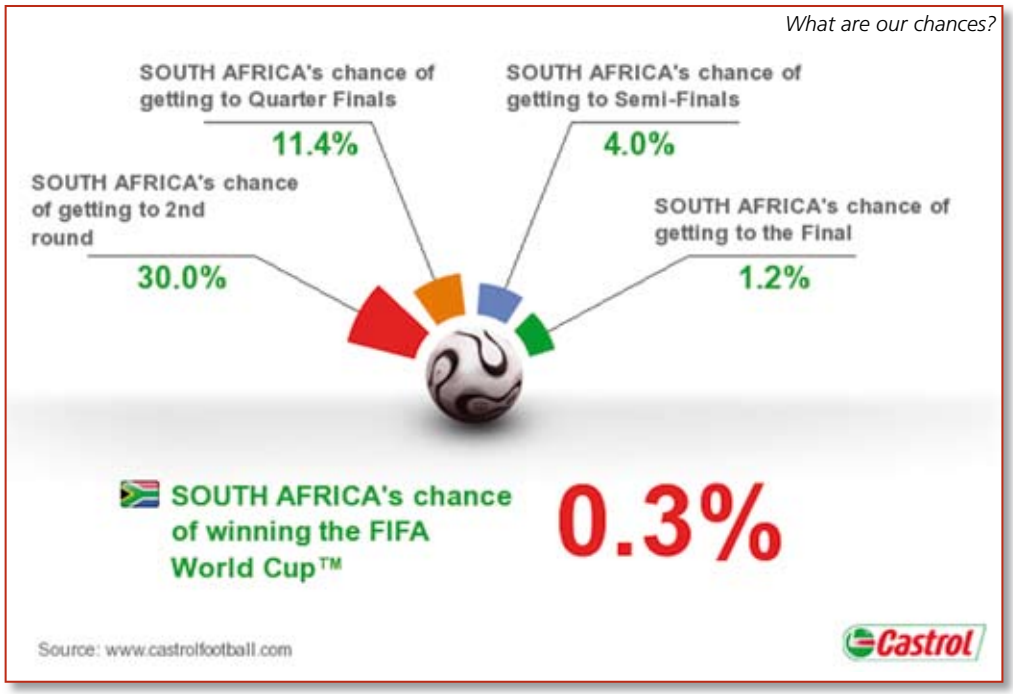
The world's eyes will be gazing upon South Africa with much interest and excitement in June and July this year. South Africa is relishing the opportunity to prove to everyone that we are not only an awesome country but that we know a thing or two about showcasing high-profile sports events. While I enjoy a good game of soccer, I also have a fascination with the mathematics that governs 'the beautiful game'. As an educator, I always try to find innovative ways of articulating and describing the science or maths behind things, but the challenge is to make it 'understandable'.

Maths and soccer

There is so much maths within the great game of soccer. For example: the digital signals that transport the satellite images involve binary code, the net that covers the match ball is a geometric marvel, the angle at which you must strike the ball to make it curve, the best place for a goalie to stand to make the striking angle smaller. In addition, the match statistics are incredibly profound indicators that are used to determine team tactics and strategies development, match betting, the selection process involving the teams, the lottery for the allocation of the tickets, the costs of running the event, the economic impact that it has on a country – the list is endless.

Predictions for Group A.

What are our chances?



A crystal ball

I would like to focus this article on one aspect that drives most people to watch the game of soccer, namely will *my team* win the match? This is what most people care about. People can over-analyse a game and lament the poor performance of Rooney or Owen but, all that matters is: who won the game.

Wouldn't it be fantastic to own a crystal ball? We could determine if our team will win the English Premier League or the FA Cup Final. We would know if Bafana Bafana are the next world champions! Since crystal balls are a little tricky to find nowadays, a firm of maths and stats academics, who describe themselves as prediction experts, claim to have the next best thing.

The staff of the company Decision Technology have developed software that boasts a higher success rate for prediction than bookmakers, pundits and sports tipsters could ever offer. In fact, they estimate their success rate to be approximately 56% whereas the bookmakers can only muster up success rates of around 42%. They currently run a fascinating website where they have analysed vast quantities of data, crunched the numbers through some mathematical formulae and can now provide objective statistics to fans of the English Premier league. If you visit their web site, http://www.dectech.org/football_sites/football_dectech/index.php you can find fascinating insights into how your team will most likely perform.

There are categories such as: chance of the home team winning, chance of the away team winning, the chance that the teams will draw and the predicted goal difference! You can

select your favourite team and see how they would compare with any other selected team. Now, admittedly, this is cool for a fan of English Premier soccer but the question that will inevitably arise is, what about the analysis of the FIFA World Cup™ for 2010? Fortunately, Castrol had the vision to set up a website that tackles this exact question.

Castrol has collaborated with Decision Technology and put together an awesome web site. This site will give you statistical analysis of teams, players, rankings, predictions of who will win each pool, who is most likely to make it through to the finals, and so on. This is definitely worth a visit! http://www.castrolfootball.com/predictor/

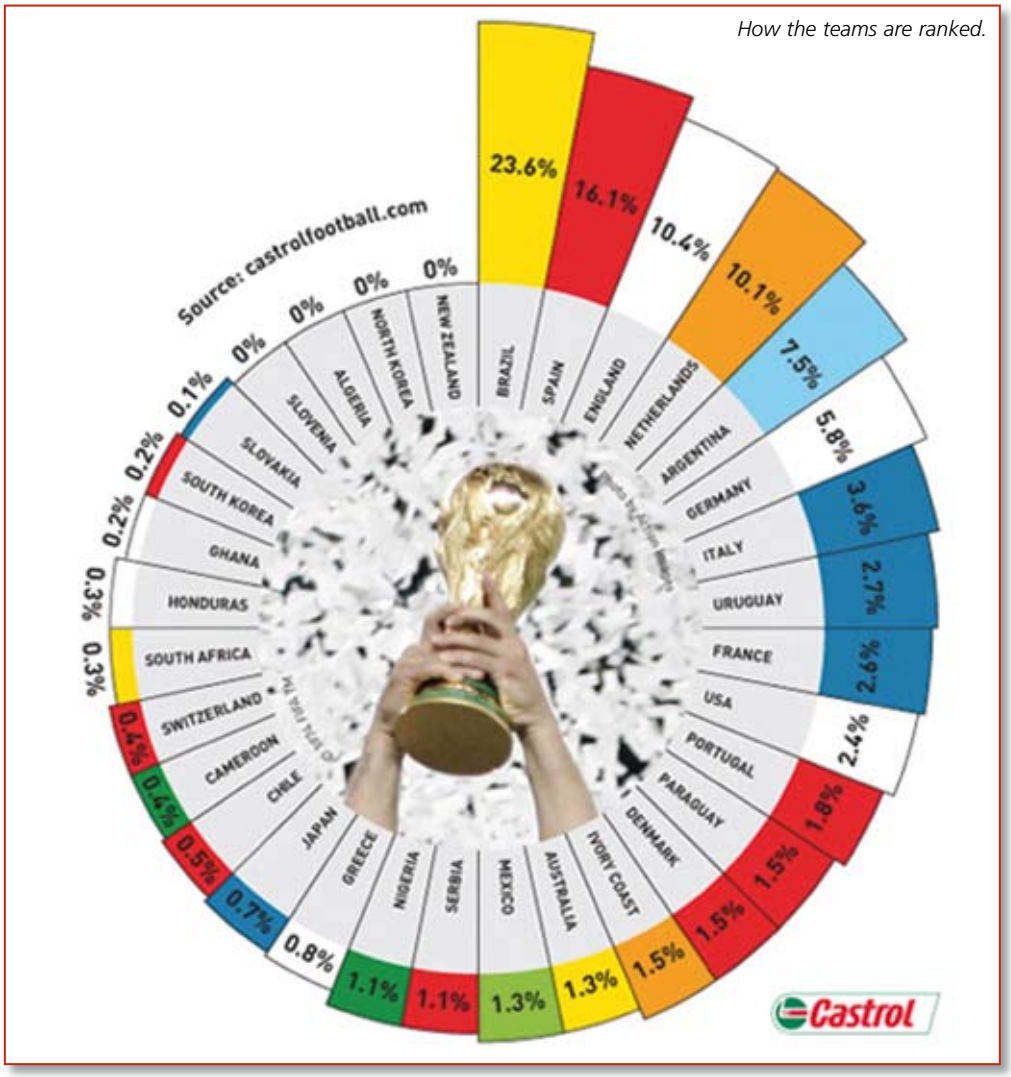
Data capture

In order to appreciate the sophistication and the style with which the prediction formulae are generated, it should be noted that a major data-capturing exercise took place to allow the final results to be more credible and objective. As an example, each player was individually allocated points, which were derived from every single pass, loss of possession, tackle and shot at goal. It is also determined by the zones in the field where the player received his passes and from where on the field he made successful passes or shots at goal. All these details play a major role in determining who the most successful offensive and defensive players are. Points are deducted for unsuccessful passes and tackles and will also depend on where these passes and tackles took place in terms of the zones located on the field. Once all the numbers have been crunched, each player is given a score out of 1 000. The higher the score the more talented the player.

How will we do?

So are you wondering where South Africa will be placed? Who will win the World Cup for 2010? Well I have saved you the effort and searched for these very answers.

South Africa has a 30% chance of making it to the second round, an 11.4% chance of making the quarter finals, a 4% chance of making the semi-finals and a 1.2% chance of getting to the finals. Their chance of winning the World Cup is listed as a mere 0.3%. If you have a basic grasp



How the teams are ranked.

of mathematical knowledge then you might get the impression that our friends at Castrol do not hold out too much hope for our boys in yellow.

While this may be disappointing for you to read, there is potentially some good news. These predictions are only correct 56% of the time so there is a 44% chance that Bafana Bafana could surprise everyone! I will go into this a little later in the article.

So who are the teams that will most likely take the top four positions? Brazil (23.6%), Spain (16.1%), England (10.4%) and The Netherlands (10.1%). The good news is that New Zealand has been placed last with 0% (maybe rugby is more their thing, after the Springboks of course!).

See the diagrams for more information.

Now to the maths

So how do they make these predictions? Where do they get their data from? What data do they collect? What is the magical maths formula that gives them the power of the betting gods? According to Decision Technology, the maths formula for making your predictions is:

$$P(n) = \frac{\lambda ne - \lambda}{n!}$$

Here is a brief explanation of the above equation:

'n' is the number of goals scored, 'λ'is the expected number of goals, 'e' is a natural logarithm and the exclamation mark is 'factorial', a function of 'n'. P is the probability distribution of goals scored.

Now for most people this looks quite complicated and better left to the maths and stats wizards. Perhaps you might have a more reliable method of predicting winning teams? Maybe your formula makes more sense? I must confess, I can follow most of the formula except for 'λ'. How are you supposed to know what the expected number of goals is going to be? Perhaps this is a hint as to why the predictions are correct only 56% of time!

When asked about the approach his firm takes to provide the predictions, Dr Henry Stott, director of Decision Technology and visiting fellow at Warwick University, said: 'Our modelling technique involves▷▷

1 (2)	L. Messi	FORWARD	BARCELONA	PRIMERA LIGA	980
2 (1)	C. Ronaldo	MIDFIELDER	R MADRID	PRIMERA LIGA	930
3 (5)	F. Torres	FORWARD	LIVERPOOL	PREMIER LEAGUE	909
4 (2)	T. Henry	FORWARD	BARCELONA	PRIMERA LIGA	881
5 (4)	G. Piqué	DEFENDER	BARCELONA	PRIMERA LIGA	877
6 (6)	D. Villa	FORWARD	VALENCIA	PRIMERA LIGA	866
7 (9)	D. van Buyten	DEFENDER	BAYERN	BUNDESLIGA	851
8 (17)	D. Drogba	FORWARD	CHELSEA	PREMIER LEAGUE	829
9 (25)	W. Rooney	FORWARD	MAN UNITED	PREMIER LEAGUE	825
10 (8)	D. Alves	DEFENDER	BARCELONA	PRIMERA LIGA	825

maximum likelihood estimation and a kind of rational probabilistic analysis to predict what the outcome of a match will be.'

Hmmm! Sounds like gibberish to me! So with a little research, I discovered that what he meant to say was: 'We analyse *huge* quantities of statistics which we gather on *each* player, *each* team, *each* match, *each* score, and so on, and we use some statistical formulae to establish patterns and the chances (probability) that teams will win'. Let us look into the type of data that they examine:

The computer has been programmed to study the scorelines of more than 6 000 games between 200 countries since 2002 and developed forecasts for each match at the initial group stage.

The system seems to be quite accurate (or so it is claimed) – it has correctly predicted the outcomes of about 56% of Premiership matches since 2002! This is far better and more consistent than anyone else – fans no longer need to rely on advice from soccer-loving friends and listening, for example to newspaper tipsters or silly authors of articles in *Quest* magazine, who score on average about 44%.

'We knew we were on to something at the 2002 World Cup when, despite France being 10-1 on to beat Senegal, they lost – an outcome which we had said was a 25% chance,' said Stott. He and his colleagues were so convinced they would get it right more often than anyone else that they bet £50 000 of their own money on their predictions.

The process of collecting data is incredibly sophisticated and it is evident that a lot of thought went into the project. Take, for example, data collected on individual players: they look at number of goals scored, success of tackles made in each match, failure of tackles in each match, the locations where the tackling took place (a player scores more points if he makes a successful tackle in certain 'zones' that are mapped onto a soccer field), they look at the number of successful passes, the number of poor passes, shots on goal, misses, in which zones these took place, and so on and so on. You can appreciate that to watch a *full* game – monitoring just one player at a time for every game they have ever played and every moment they interact with the ball is a highly intricate process and the data have given the Castrol team an opportunity to rate the players out of 1 000 (using a combination of all the criteria above). According to this method, the top 10 individual players are as listed in the table left.

While all this is interesting to most people, did any of you realise that there is just a little over 50% accuracy in predicting the winning teams? Effectively this is barely more successful than flipping a coin (i.e chance). I think there are many factors that have been left out of their calculations:

- The incentives offered for every team win – judging by the media reports, Bafana Bafana might be so inspired by the financial perks that they outplay their own predicted performance!
- The vuvuzela factor – the cacophony of notes that are blasted around the stadium might affect the performance of the visiting soccer teams!
- Some players might be curious to sample the local cuisine, like Mamma's Hot curry bunny chow before a match fixture and this could have an impact on their level of play.
- A player might fall head-overheels in love with a local beauty and this might impact on his concentration levels.

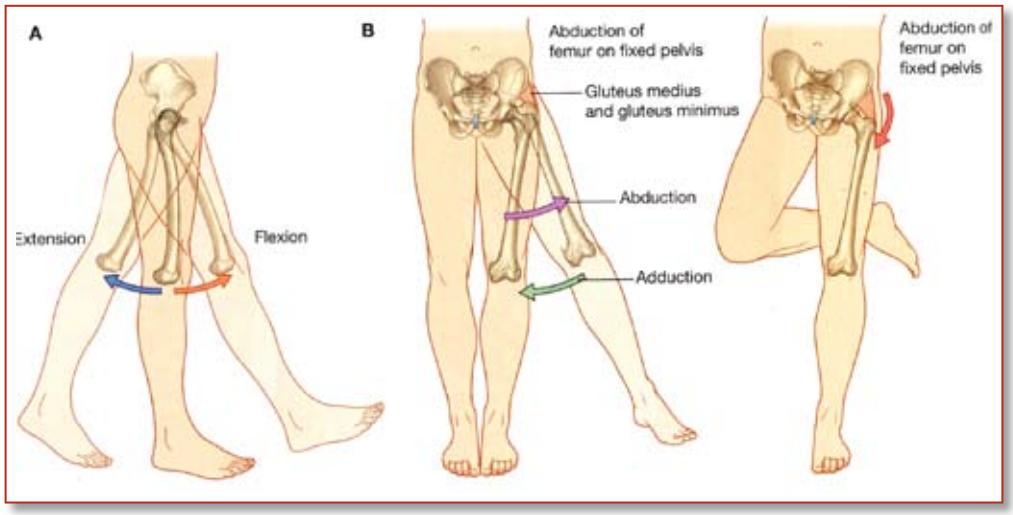
You can see from some of the scenarios above, that while they might appear to be rather extreme, obvious factors such as fatigue, illness, physical fitness, national pride, injury, emotional state, media reporting and weather will all affect the performance of the players – these are factors that are not included in the number-crunching formulae. The fact that their main formula requires you to guestimate the number of goals that will be scored in a match would obviously affect the outcome of your prediction!

It is these aspects and many others that will determine the final outcomes. While the numbers indicate that Brazil and Spain are the teams to back, I still feel that Bafana Bafana are going to give the predictors a good run for their money. □

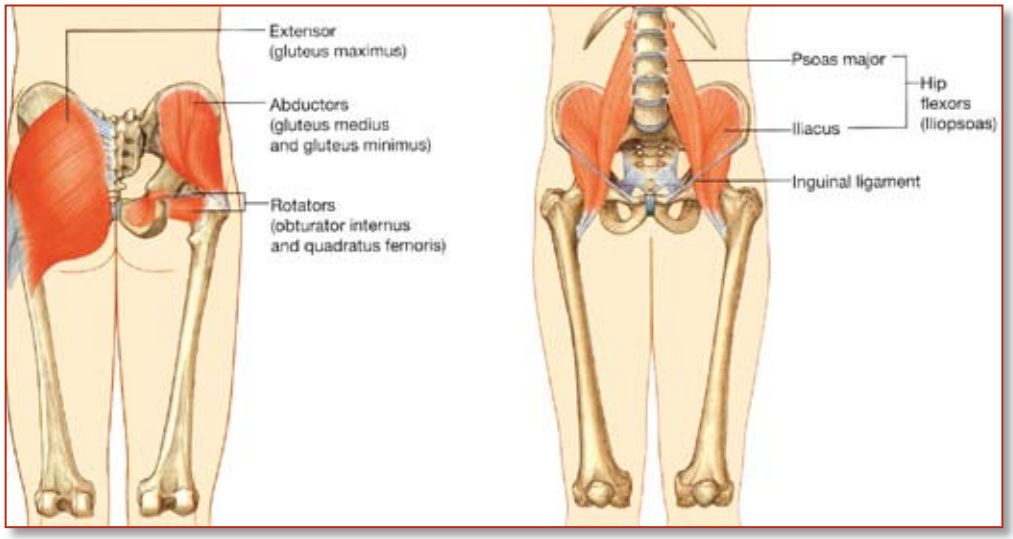
Steve Sherman is the Managing Director of Living Maths. He was also vice captain for the under-10c soccer team. Living Maths is an NGO that is focused on bringing Maths to the masses using innovative approaches while making it exciting. Visit their website on www.livingmaths.com to find out more.

Kicking a soccer ball

What is involved in kicking a soccer ball?



Movement of the hip joint. A Flexion and extention B Abduction and adduction.



The picture on the left shows the muscles of the gluteal (backside) region. The picture on the right shows the muscles that flex the hips.

Muscular action during kicking preparation (right-footed kick)

Body part	Action	Muscles
Trunk	Stabilisation of rotation to the right	Abdominals, psoas major, erector spinae and spinal postural muscles
Right hip	Extension	Gluteus maximus and hamstring group
Left hip	External rotation and eccentric extension	Gluteus med, gluteus min, hamstring group and adductor magnus
Right knee	Flexion	Hamstring group and popliteus
Left knee	Eccentric extension	Quadricep group
Right ankle	Plantarflexion	Plantarflexors
Left ankle	Eccentric plantarflexion	Plantarflexors
Left shoulder	Abduction	Middle and anterior deltoid and supraspinatus

Kicking a ball involves the coordination of many muscles in the leg, although the rest of the body is also involved in stabilising the person doing the kicking. A soccer kick lasts for around five seconds. During this action all the muscles detailed in the table below come into play.

We can break the kick into six stages:

- the approach
- plant-foot forces
- swing-limb loading
- hip flexion and knee extension
- foot contact
- follow-through.

The approach

An experienced soccer player will pace his approach to the ball. The most efficient approach is diagonal to the ball. This diagonal approach allows kick that produces the best ball speed.

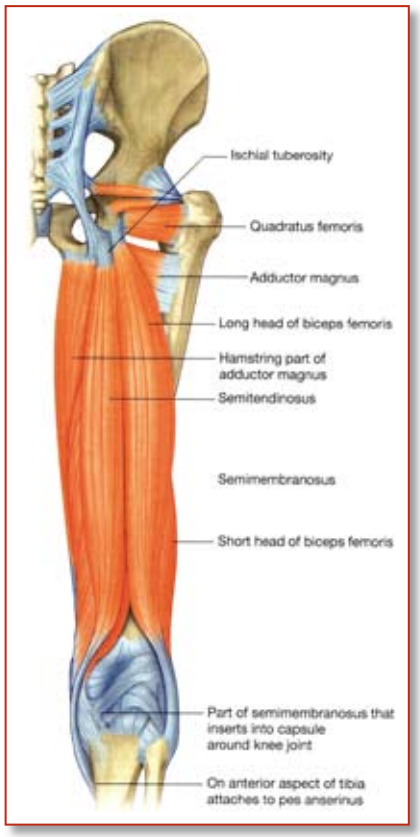
Plant-foot forces

Skilled soccer players kick fast and produce good ground reaction forces in all directions. When kicking, there is a direct relationship between the direction that the plant foot faces and the direction in which the ball travels. The optimal foot plant position for accurate direction is perpendicular to a line drawn through the centre of the ball for a straight kick.

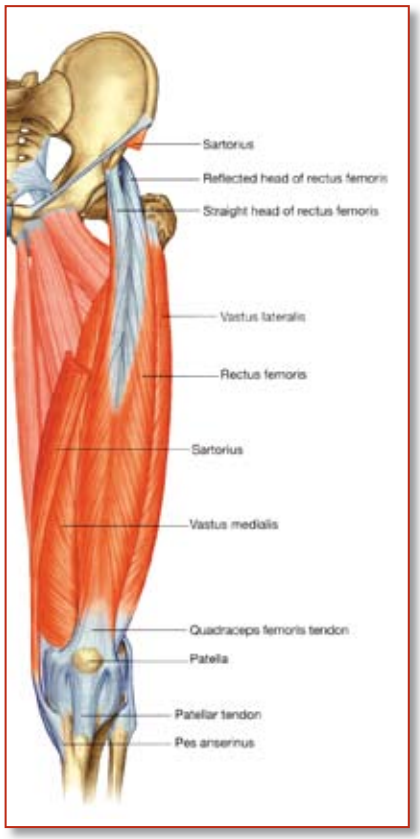
Swing-limb loading

The next phase within the biomechanics of the kick is the swinging or cocking of the kicking limb in preparation for the downward motion towards the ball. During this phase the kicker's eyes are focused on the ball; the opposite arm to the kicking leg is raised and pointed in the kicking direction to counter-balance the rotating body. As the plant foot strikes the ground adjacent to the ball, the kicking leg is extending and the knee is flexing. The purpose here is to store elastic energy as the swinging limb passively stretches to allow a greater transfer of force to the ball during the downward phase of the kick.

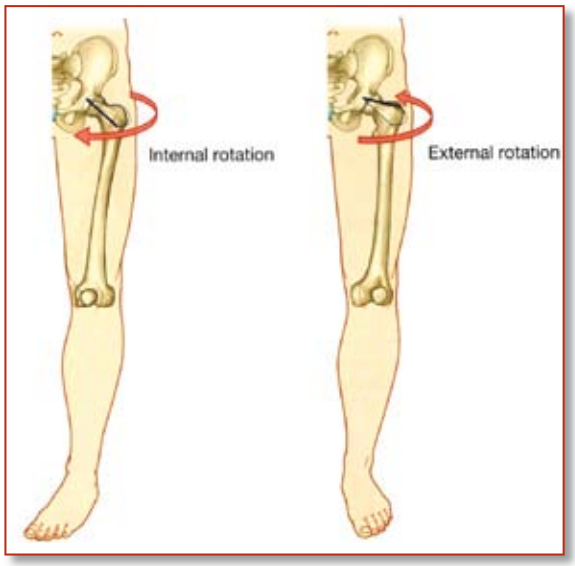
Before the end of the swing phase when the hip is nearly fully extended and the knee flexed, the leg is slowed eccentrically by the hip flexors and knee extensors. This is the phase of the kick



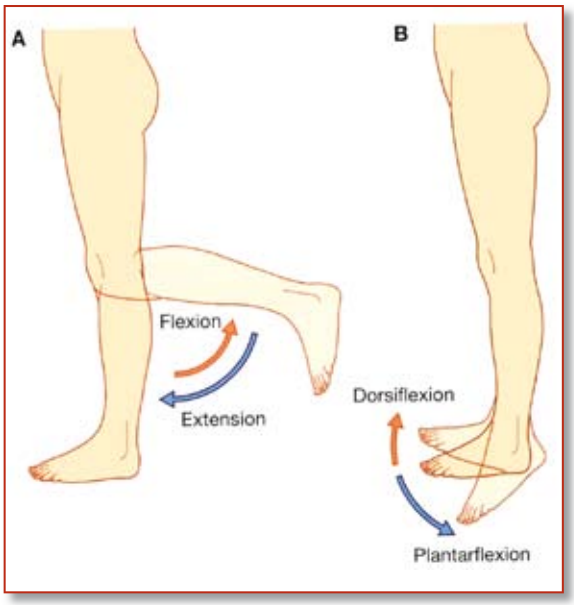
The front of the thigh, showing the muscles.



The front of the hip, showing the muscles.



Movement of the hip joint. External and internal rotation.



Movement of the knee and ankle. S Knee flexion and extension. B Ankle dorsiflexion and plantarflexion.

where there is maximal eccentric activity in the knee extensors.

Hip flexion and knee extension

The powerful hip flexors initiate this next phase of the kick. The thigh is swung forward and downward with a concomitant forward rotation of the lower leg/foot. As the forward thigh movement slows, the leg/foot begins to accelerate because of the combined effect of the transfer of momentum and release of stored elastic energy in the knee extensors. The knee extensors then powerfully contract to swing the leg and foot forwards towards the ball.

As the knee of the kicking leg passes over the ball, it is forcefully extended while the foot is forcefully plantarflexed. This exposes the inside top part of the foot, which is propelled at the ball.

There is a linear (straight line) relationship between foot velocity and resultant ball velocity. Foot speed is governed by a combination of hip rotational torque, hip flexor strength and quadriceps strength. At the end of the swing phase, just prior to ball/foot contact, the hamstrings are maximally active to slow the leg eccentrically. This phenomenon is known as the 'soccer paradox', where the knee flexors are maximally active during knee extension and the knee extensors are maximally active during knee flexion.

Foot contact with the ball

At this point the positions of the kicker's feet are critical to the success of the kick. According to various studies, the foot is in contact with the ball for 6-16 milliseconds, depending on how well inflated the ball is. But contact times these days are likely to be nearer 16 milliseconds or longer, as the pressure of the ball has been reduced since the most recent analysis of contact times.

At the point of impact 15% of the kinetic energy of the swinging limb is transferred to the ball. The rest is dissipated by the eccentric activity of the hamstring muscle group to slow the limb down. And because of the large forces involved, this stage in the kicking action is the most likely to produce injury to the hamstrings.

At the instant of impact on the kicking leg, the hip and knee are slightly flexed and the foot is moving upwards and forwards.

Follow-through

The follow-through of the kick serves two purposes: to keep the foot in contact with the ball for longer; and to guard against injury. As in all ballistic movements, a longer contact time will maximise the transfer of momentum to the ball and thus increase its speed. The body protects itself from injury by gradually dissipating the kinetic and elastic forces generated by the swinging, kicking limb after contact. Any sudden slowing of the limb would increase the risk of hamstring strain. □

Definitions

Extension: a movement that straightens a body part. In the hip, extension is a backward movement.
Flexion: a bending movement. In the knee, this is the action that bends the knee.
Abduction: a motion that pulls the body part away from the midline. In the shoulder, this essentially means the movement that raises the arm.
Adduction: a motion that pulls the body part towards the midline.
External rotation: a movement that rotates the body part away from the midline, in the case of the hip, a movement that rolls the hip away from the body.
Eccentric extension: the muscle is lengthening while it is contracting, rather than shortening.
Plantarflexion: a movement in which the whole foot is depressed, as though pressing an accelerator pedle. This occurs from the ankle.

Sports medicine and soccer

Soccer players, like other athletes, have problems with injuries.

Soccer is one of the most popular sports in the world, with an estimated 240 million (in 2000) to 265 million (in 2006) players participating in the game. The sport involves intermittent walking, jogging, running and sprinting, and has a higher incidence of injuries than rugby, volleyball, field hockey, cycling, boxing, swimming and basketball. In 2001 it was reported to have injury rates of 1 000 times higher than for industrial occupations generally regarded as high risk.

Lower limb injuries

Eighty-seven per cent of soccer injuries involve the lower limb. Two-thirds of injuries occur during competitive matches where the speed and intensity of play are far greater. The most common site of injury in male players is the ankle (20%) followed by the upper leg (17%), and the knee (15%), while in female players the knee is the most commonly injured site, accounting for 23% of injuries, with the ankle and upper leg injuries accounting for 21% and 16% respectively.

Overuse injuries account for 2% of all soccer injuries and 39% of knee injuries in soccer are caused by ligament injuries.

Collapse

What causes collapse in soccer players? The most common cause is an injury – unless the player is deliberately 'diving' to try to stop play. However, legitimate causes of collape can be divided into contact and non-contact causes.

Contact causes include:

- Head injuries
- Spine injuries
- Muscle injuries
- Less commonly, chest wall injuries and blunt injuries to the abdomen or groin

Non-contact causes include:

- Muscle and ligament strains and tears
- Muscle cramps
- Less common causes include cardiac events, heatstroke, hypoglycaemia (low blood sugar) and sudden drops in blood pressure

Very uncommonly, natural phenomena such as lightning may cause players to collapse. In a game in Johannesburg, a number of players collapsed after being struck by lightning and the match was abandoned.

Doping in soccer

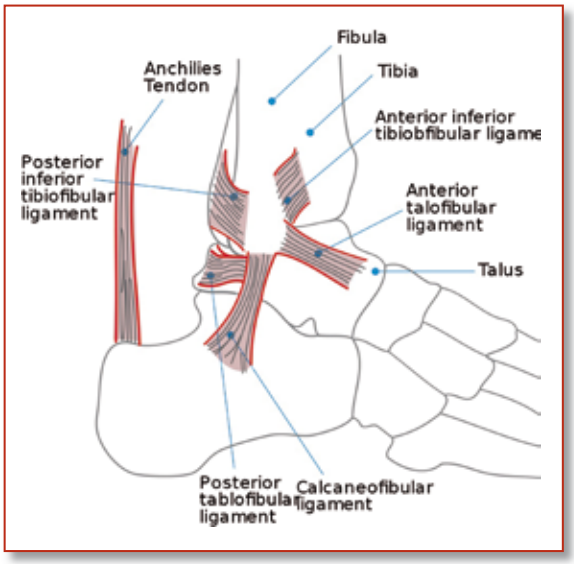
In sport the use of pharmacological agents or other biological or non-biological methods to artificially enhance performance is called 'doping'. This is regarded as unethical and is illegal.

An elite soccer player is hardly ever out of competition because of the long soccer season. During major competitions, such as the 2010 FIFA World Cup™, urine samples are collected from two randomly selected players from each team after each match. Blood tests may also be requested. Out of season, doping control agencies know where every player is at all times.

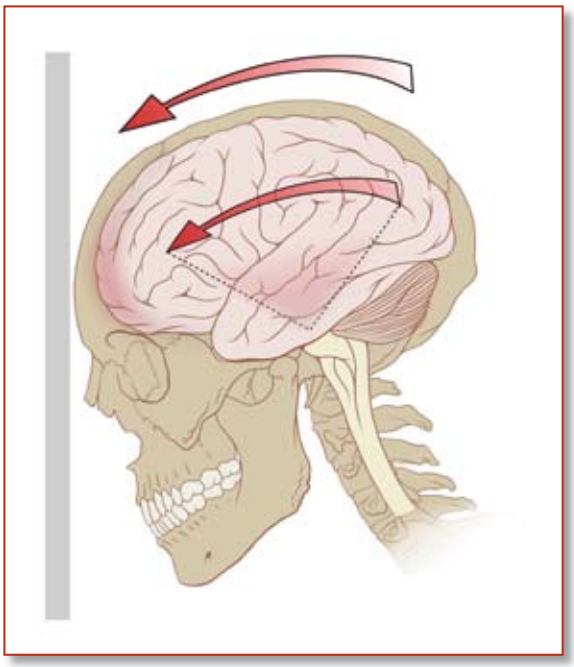
All medicines that a player may take for legitimate reasons are declared and the urine sample is divided into and A and a B sample and placed in tamper-proof containers. The containers are then transported under strict chain-of-custody rules to an accredited dope control laboratory. If banned substances are found in the A sample, the player may ask to be present at the testing of the B sample.

If the player is found to have banned substances in his or her blood or urine then they may be banned for a period that can vary between months or life.

In a recent analysis it was estimated that football has well over 200 000 elite players throughout the world and in excess of 20 000 doping control tests are conducted annually on these players. According to this analysis, the incidence of doping in football is quite low (0.4%) and the vast majority of adverse analytical findings are due to recreational drugs including cannabis and cocaine, with only 0.07% of positive cases due to abuse of anabolic steroids. At the 2006 FIFA World Cup™ there was not a single positive test. In fact, in the period between 1994 and 2005 at major FIFA competitions, only four urine samples tested positive: two for ephedrine/pseudoephedrine, one for cannabis and one for nandrolone.

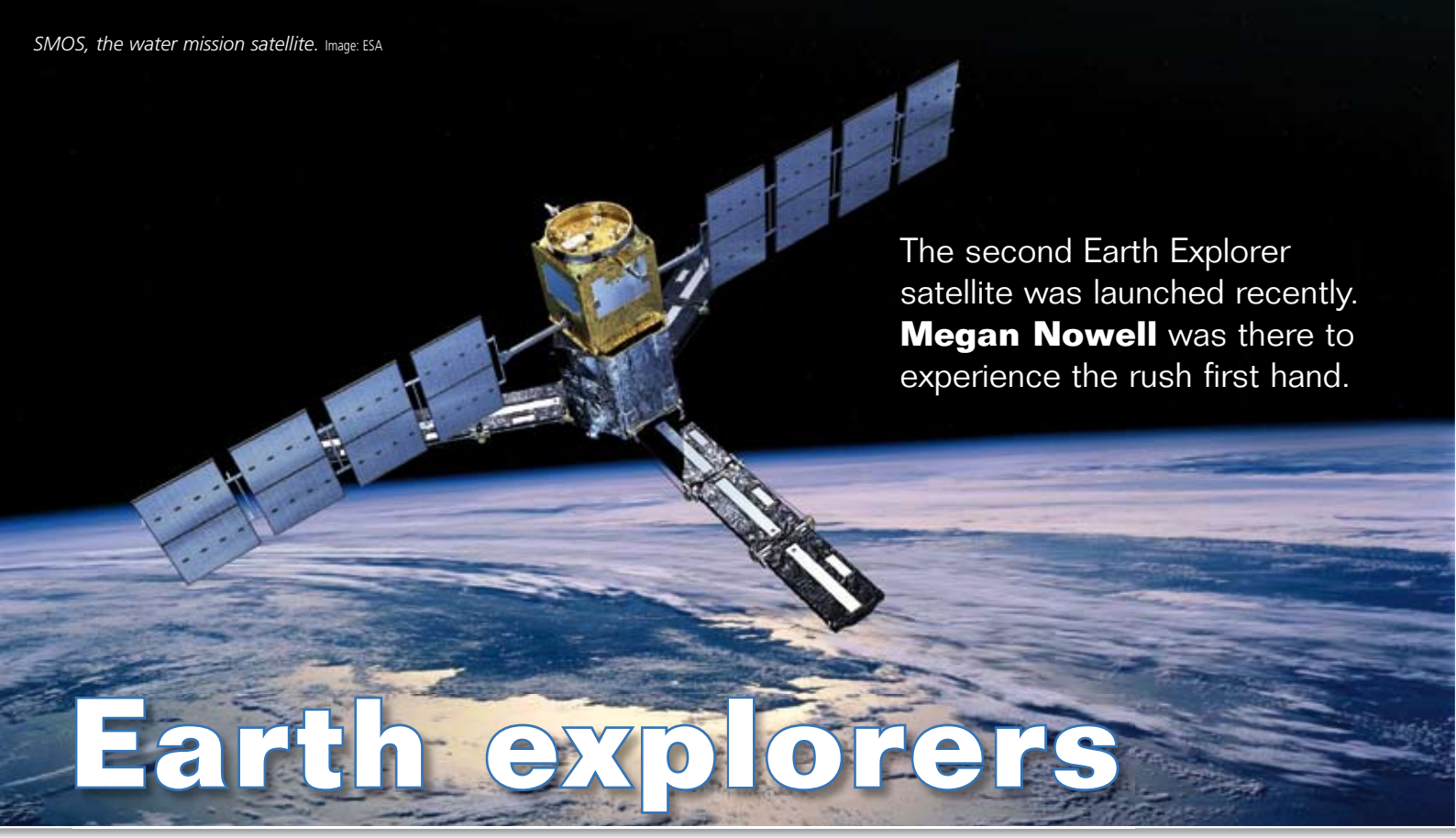


A diagram of the ankle joint.



Acceleration and deceleration forces can cause brain injuries as the brain hits the inside of the skull.

SMOS, the water mission satellite. Image: ESA



The second Earth Explorer satellite was launched recently. **Megan Nowell** was there to experience the rush first hand.

Earth explorers

GOCE, the gravity mission satellite. Image: ESA

Left: Megan Nowell at the launch of SMOS. Image: Leanne Talbot-Nowell

Definitions

Hydrosphere: the part of the Earth that is composed of water.
Cryosphere: areas of the Earth where the surface is frozen.
Atmosphere: the layers of gases surrounding the Earth.
Biosphere: the part of the Earth that contains living organisms.

3…2…1, SMOS! The suspense was tangible as the water mission satellite was launched into orbit. Scientists had their eyes glued to two large screens. Mission managers and rocket engineers gripped their seats with white knuckles and waited as green light after green light marked the safe launch of the second of ESA's Earth Explorer satellites, SMOS (Soil Moisture and Ocean Salinity).

SMOS was launched from the Plesetsk Cosmodrome in Russia on 2 November 2009.

The Living Planet Programme of the European Space Agency will see the launch of a total of six Earth Explorer satellites, which will monitor our planet from space. These missions will focus on the Earth's interior, its hydrosphere, cryosphere, atmosphere, and the biosphere in order to provide information on global environmental change.

The Earth Explorer programme

GOCE: the gravity mission

The first of the Earth Explorers to be launched was GOCE, the gravity mission. GOCE (or Gravity Field and Steady-State Ocean Circulation Explorer for the long-winded) measures and models the Earth's gravity field with unmatched accuracy at a spatial resolution of around 100 km. Anomalies in the gravity field can be detected with an accuracy of 1 mGal, impressive for an instrument circling 255 km above the Earth's surface.

mGal: a unit of acceleration used to measure gravity.

SMOS: the water mission

SMOS, the water mission, will provide crucial information to fill the gaps in our understanding of Earth's water cycle.

Water cycle: the continual cycling of water between the land, the ocean and the atmosphere.

Monitoring variations of soil moisture and the salinity of surface water will not only advance weather and climate predictions, but will also contribute to extreme-event forecasting. It will allow us to understand ocean currents, and will be useful in areas such as agriculture and water resource management. The data obtained by SMOS will provide a global image of surface soil moisture every three days at a spatial resolution of 25-50 km. Every 30 days, ocean salinity maps at a spatial resolution of 200 x 2 000 km will be available.

CryoSat: the ice mission

CryoSat is the next Explorer that will be launched in 2010; the ice mission satellite. The satellite will be able to make accurate measurements of floating sea ice and to detect elevation changes on the surface of continental ice sheets, which will make Arctic and Antarctic science a lot easier. The precise measurements with respect to time (called the temporal resolution) that this satellite will be able to make will allow for seasonal and inter-annual variation to be detected for sea-ice, ice caps and glaciers alike.

ADM-Aeolus: the wind mission

2011 will see the first space mission that will be able to measure wind profiles on a global scale. ADM-Aeolus, the Atmospheric Dynamics Mission, will be able to accurately measure wind profiles up to an altitude of 30 km, improving weather predictions and our understanding of the processes relevant to climate variation. It is hoped that the highly sophisticated Doppler wind lidar instrument will improve our relationship with weather forecasters on a global scale.

Doppler wind lidar: a laser instrument used to measure wind.

Swarm: the magnetic field mission

Swarm, a constellation of three satellites, will make up the magnetic field mission, also to be launched in 2011.

ADM-Aeolus, the wind mission satellite. Image: ESA

The magnetic field: the magnetic forces surrounding the Earth.

Magnetic field measurements taken at Earth's surface may be influenced by magnetised rocks, so this mission will provide new insights into Earth's interior as well as information about the interaction of the magnetic field with other physical quantities that also play a role in the Earth system. The high-precision, high-resolution measurements will redefine geomagnetic field models as we know them.

EarthCARE: the cloud mission

The sixth Earth Explorer, which will be launched in 2013, is the cloud and aerosol mission, EarthCARE. This mission is designed to give a better understanding of the interactions between the cloud, radiative and aerosol processes that play such a vital role in climate regulation.

Radiative processes: processes that occur through radiation.
Aerosol: a cloud of solid or liquid particles in a gas.

The final mission: watch this space

A seventh and final Earth Explorer mission is still to be selected from three candidates currently undergoing feasibility studies. Candidate mission number 1 would take global biomass measurements, appealing to the tree-huggers and those interested in global vegetation patterns. Hydrologists in cold areas are hoping candidate mission number 2 will be chosen to provide high-resolution data on snow and ice. Candidate mission number 3 would focus on understanding the processes that link trace gases, radiation and chemistry to climate.

Biomass: the total mass of living organisms, in this case vegetation.
Hydrologist: a person who studies the water cycle.

The impact of global change on the Earth system needs to be monitored and assessed as a whole. This fleet of Earth Explorers will provide data to the scientific community on a scale previously unimaginable, enabling a better understanding of the Earth system, and the likely impacts of future global trends. These missions are in response to a demand for accurate satellite data with practical applications and have been developed in close cooperation with the scientific community. This user-driven approach will help us to understand the impact that human activities have on Earth's natural processes. Satellite data can be acquired free of charge for research purposes from ESA. For more information, go to www.esa.int/livingplanet. □

Megan Nowell is a Master's student in conservation ecology at Stellenbosch University, supervised by Dr David Le Maitre (CSIR, Stellenbosch) and Prof Karen Esler (Conservation Ecology, Stellenbosch University). Her research is funded by ASSET Research and the Water Research Commission, and focuses on the hydrological impacts of clearing invasive alien vegetation on the Agulhas Plain. Megan works with satellite imagery and GIS to map and monitor the impacts of invasive alien plants.

Restoration in South Africa

James Blignaut and colleagues explain the importance of ecological restoration in the changing South African landscape.

Restoration of dunes after strip mining. Image: Marco Pauw

This is interesting

Restoration can provide a wide range of direct and indirect benefits to society. However, there are very few projects that have attempted to properly quantify those benefits and present them in such a way that society is motivated to invest in restoration. Describing and quantifying these benefits requires people who understand ecosystems and their restoration, as well as people who know how to assess benefits. However, it is not a matter of simply combining knowledge. We need to understand how differently our sciences view the world and organise their knowledge of it. For example, ecologists are concerned about how ecosystems function and how their restoration may be affected by their history, location and context. Economists are more interested in flows of goods and services to and through society and less so in where things are. Developing the shared understanding needed to provide a thorough and sound assessment of the benefits requires us to find (a) ways of linking the information that ecologists provide to the benefits that economists can value and (b) ways of sharing these benefits with society.

Restoration is one example of the very complex problems faced by society. There are many such problems that will require co-operation between disciplines and the active participation of society in the search for the solutions.

There is a clear message in this: the era when single disciplines and scientists alone found solutions is rapidly passing. Scientists, government, industry and society need to work together to find and implement solutions. Together we can do much better than we can do individually!

What is restoration?

Our human population continues to grow at an unprecedented rate, demanding ever-increasing amounts of goods and services from the natural ecosystems upon which we depend. No part of the planet has been left untouched, and many areas are degraded. We have scarred (or transformed) landscapes by removing natural vegetation to plant crops, dam rivers, mine minerals and to gain access to previously inaccessible areas. In the process, we have tampered with the very fabric of the ecosystems that we need for our survival.

But all is not lost. *Ecological restoration* is the process of repairing these affected ecosystems, with the main goal of bringing them back to some level of health, integrity and self-sustainability. If the size of the impact is small and manageable, all that may be needed is a gentle prod to shift the ecosystem back (*passive restoration*) towards its natural state. If this does not happen within a reasonable time frame, active measures might need to be put in place (*active restoration*), such as the re-introduction of important species or the removal of alien species.

If the level of transformation is too large or severe for restoration, *ecological rehabilitation* may be a better option. This is where some of the important functions of the system (e.g. grazing capacity) are recovered, but not to the same natural state as before. Rehabilitation typically occurs on post-mining sites and sites heavily affected by overgrazing.

If ecosystems are so badly damaged that they can no longer recover, even with the best of efforts, they are usually reassigned to a different function (*reallocation*). So, for example old croplands with soils that have been ploughed and fertilised for years may be best used for housing developments, thereby leaving more intact ecosystems untouched. It is obviously best to avoid the need for restoration altogether by balancing wise management with sustainable growth, but sadly this has not always been the case, and the science of restoration is needed to develop the appropriate technologies for ecosystem repair.

Natural capital

A recent development is the concept of restoring natural capital (RNC – see also www.rncalliance.org). RNC is a somewhat larger or broader concept than ecological restoration as defined above. It refers to all investments in renewable and cultivated natural capital stocks and their maintenance in ways that will improve the functions of both natural and human-managed ecosystems. At the same time these investments contribute to the socio-economic wellbeing of people through holistic restoration of ecosystems, ecologically sound improvements to lands managed as production systems for useful purposes, improvements in the utilisation of biological resources, and the establishment or enhancement of socio-economic systems that facilitate the incorporation of knowledge and awareness of the value of natural capital into daily activities.

Investing in renewable and cultivated natural capital is like putting money in the bank, generating interest in terms of ecological goods and services (EGS) indefinitely. However, the 'banks' (ecosystems) require effective management to protect or augment capital and to prevent its dissipation for short-term profit.

Why is restoration necessary?

Overgrazing, surface mining, ploughing and abandonment of fields all remove the natural vegetation cover. Bare soil, exposed to sun and beating rain, often becomes smooth and baked like a tennis court. Rainwater cannot penetrate the hard ground but runs off, carrying away leaves and seeds. Dry top-soil, without living roots to hold it together, turns to rivers of mud that silt up dams and pollute streams. Wind further scours the bare surface and the remaining topsoil spirals away as dust devils.

Such damaged land can heal itself – but this may take hundreds or even thousands of years. The growing human population needs productive land for food and large tracts of natural vegetation to absorb carbon dioxide and stimulate the imagination, uplift the spirit and soothe weary urban eyes. We cannot wait centuries for nature to heal the damage we cause through our daily activities. This is why restoration must be proactive.

– a case study

Government, businesses, NGOs and individuals need to invest and engage in active restoration to hasten the recovery processes. Major steps in restoration include the development of structures and soil works that trap water and improve infiltration, 'bandages' such as mulch, textile or branches to hold the soil, and sowing or replanting plants that will bring life back to the land and attract the pollinating birds and insects necessary to make the vegetation self sustaining.

The importance of restoration is highlighted and discussed, complete with international case studies, in Chapter 9 of the Economics of Ecosystems and Biodiversity project (TEEB) and can be downloaded at http://www.teebweb.org/LinkClick.aspx?fileticket=9NUqttjb3bo%3d&tabid=1019&language=en-US.

An example of restoration research in South Africa

Currently ASSET Research (www.assetresearch.org.za), a section 21 Public Benefit Organisation that endeavours to develop capacity and advance the ecology/economic/scientific knowledge frontier, is engaged, under contract from the Water Research Commission (www.wrc.org.za), with significant co-funding from the Working for Water programme, to assess and quantify the impact of restoration. ASSET awarded a total of 13 scholarships to 12 Masters' and one PhD candidate attached to six universities to conduct an in-depth analysis of the ecological, hydrological and economic impacts of restoration at eight sites across South Africa. The sites, four of which are discussed in the accompanying boxes, have been carefully selected to be representative of South Africa's rich biodiversity. Another selection criterion was the need for historic data and a restoration history. In each of the cases the ASSET Research team collaborates with partners, that include the Working for Water programme, Flower Valley, the Ostrich Business Chamber, Exxaro and AWARD, to a) benefit from these organisations' experiences, and b) to add value to the ongoing initiatives. In practice this implies that for each of the research sites a combination, or team, of hydrology, ecology and economic students assess the impact of restoration in collaboration with the resident research/organisation and his/her university supervisor.

Student colloquiums are organised approximately every three to four months to provide feedback to the broader stakeholder community, and to enhance multi- and interdisciplinary research. Student colloquiums provide a non-threatening environment where research progress, as well as difficult conceptual and methodological issues, is discussed. Students are provided with an opportunity to engage with researchers and students from other institutions and organisations and disciplines while having the opportunity to communicate their research findings. These student colloquiums are invaluable in offering students the necessary practice in public speaking and science communication.

The flagship of the project is the multi-disciplinary PhD study that seeks to learn from and distil the information from the various Masters' studies into one systems model that could be used in policy and strategic decision-making through scenario planning. This systems model could be used, through and in interaction with various role-players and stakeholders, to develop scenarios that show what the impact of restoration under various circumstances and conditions is likely to be, based on the outcomes and the results from the eight reference sites.

It is expected that this research will demonstrate the importance of restored ecosystems to human wellbeing in the context of developing countries. In one way it is no different from other kinds of restoration work. For example, if roads are not well maintained, transport becomes more costly and economic development suffers. The only difference is that investment is now needed in the ecological infrastructure supporting those ecosystem services that are often taken for granted.

It is further expected that restored ecological services such as grazing and assured water flows are necessary, but certainly not sufficient, for an improvement in socio-economic activities such as agriculture. Despite this realisation, restoration of natural capital is one important way to address the increasingly important biophysical limits of socio-economic development. In developing countries with high numbers of rural poor relying on agriculture for their survival, this may be one of the few remaining viable options left.

This project is commissioned and funded by the Water Research Commission (Key Strategic Area 4: Water Utilisation in Agriculture)

The students

Name: Douglas Crookes
Thesis title (degree): *A meta-analysis of the ecological, hydrological and socio-economic impacts of restoring natural capital in South Africa* (PhD, Stellenbosch University)
What it means to be part of an inter-disciplinary team: It is an invaluable experience to be part of this inter-disciplinary team.

Name: Petra de Abreu
Thesis title (degree): *Restoration in the semi-arid Little Karoo, South Africa: Testing methods for re-establishing indigenous vegetation on degraded ostrich farmland and the impact of restoration on ecosystem services on degraded ostrich farmland* (MSc Conservation Biology, UCT)
What it means to be part of an inter-disciplinary team: Being a part of the Asset Research inter-disciplinary team allows me to place my research into a bigger picture between the diverse fields of natural and social sciences and economics.

Name: Thabisisani Ndhlovu
Thesis title (degree): *Prosopis clearing in the Karoo: Assessing the value of restoring Nama Karoo rangeland through the recovery of ecosystem structure, function and agricultural productivity* (MSc Conservation Ecology, Stellenbosch University)
What it means to be part of an inter-disciplinary team: I have found that looking at a problem from other points of view gives me a greater understanding of the issues being researched. ▹▹

Name: Marco Pauw
Thesis title (degree): *The ecological effects of restoration on a coastal mineral sands mine in the arid Namaqualand, South Africa* (MSc Conservation Ecology, Stellenbosch University)
What it means to be part of an inter-disciplinary team: Being part of an inter-disciplinary team teaches me to better communicate my work to people without ecological training and to appreciate that people from different disciplines value things differently.

Name: Helanya Vlok
Thesis title (degree): *Restoring natural capital: estimating the value of changes in ecosystem functions in the Nama Karoo and the Agulhas plain* (MSc Economics, Stellenbosch University)
What it means to be part of an inter-disciplinary team: Being part of a transdisciplinary team has contributed greatly to my understanding of the interrelatedness of economic, ecological and hydrological functions. I have also realised how important it is to be able to communicate discipline-specific concepts in terms that a person from any study background should be able to understand.

Name: Worship Mugido
Thesis title (degree): *A financial and cost benefit analysis of veld restoration after ostrich farming and sand dune mining* (MSc Economics, Stellenbosch University)
What it means to be part of an inter-disciplinary team: Working with colleagues from different disciplines with different skills, knowledge and personal attributes has given me new ideas and perspectives on my subject.

Name: Musiiwa Makumbe
Thesis title (degree): *The Impacts of* Prosopis *species on Groundwater Resources in Beaufort West/Britstown area, South Africa.* (MSc Environmental Science, UWC)
What it means to be part of an inter-disciplinary team: This type of study facilitates the exchange of knowledge and brings new ideas in the area of research.

Name: Megan Nowell
Thesis title (degree): *Determining the net benefits of clearing invasive alien vegetation on the Agulhas Plains* (MSc Conservation Ecology, Stellenbosch University)
What it means to be part of an inter-disciplinary team: Working with economists not only teaches us ecologists and hydrologists how to communicate outside of our realm, but also helps us to make a bigger impact with our findings.

SITE 1: Restoration of the natural veld in the Little Karoo

Research site

The study area lies between Oudtshoorn and Calitzdorp in the Little Karoo, within the Succulent Karoo Biodiversity Hotspot.

Monitoring restoration at the study site in January 2010. Image: Sue Milton

Description of the problem at the site

High densities of ostriches cause severe damage to the veld. The main problem is trampling, but overgrazing is also important. Both have destroyed the vegetation, exposing the top soil to erosion by wind and rain. The bare soil surface becomes so compacted that rain does not soak into the soil and dongas form along the old paths. The result is that seeds are not able to germinate under these conditions and natural recovery is likely to take a very long time, certainly longer than a person's lifetime.

The effects of trampling and overgrazing on the study site. Image: Sue Milton

The hypothesis being investigated at this site is that restoration will revive biodiversity and regenerate the ecosystem services on which people rely. Work at this site will evaluate the success of various methods in restoring the natural veld and the ecosystem services that it can deliver. The work will also evaluate the benefits received by the farmer and surrounding community from the restored veld against the costs incurred in the restoration of the veld.

Description of the restoration and outcomes

Two methods were employed in the restoration. The first method consisted of hand-dug holes (0.25 m deep and 1 m across) 1 m apart. The soil was loosened and sculpted in such a way that each would retain rainfall runoff. The second method was to break the soil surface using a tractor-drawn ripper. Breaking the hard caked soil surface allows both rainwater to infiltrate into the soil and plant roots to penetrate so that the plants can establish.

Bushman grass. Image: Jose Hernandez @ USDA-NRCS PLANTS Database

Naturally occurring Karoo shrub and grass seeds and seedlings (bushman grass (*Fingerhuthia africana*) and anchor karoo shrub (*Pentzia incana*) were then planted by hand into the loosened soil and a wood-chip mulch was scattered over the planted areas to improve the capacity of the soil to hold water.

Rehabilitation planting at Greylands. Image: Sue Milton

Rehabilitation planting at Morester, Oudtshoorn. Image: Sue Milton

The initial findings of the research are that these restoration methods have been successful in the short term. Restoration can be costly but farmers can reduce costs by doing the work themselves. The value of the restored and sustainably managed veld needs to be set against the restoration costs.

Who are the collaborators?

Students working on this site are Petra de Abreu (ecologist) and Worship Mugido (economist).

Collaborators in the project include ASSET Research (Prof. James Blignaut), Renu-Karoo (Prof. Sue Milton and Prof. Richard Dean), South African Ostrich Business Chamber (Susan Botha and Yvette Uys), Conservation Management Services (Ken Coetzee and Wallie Stroebel) and landowners (Joey Potgieter, Hein Jonker and Jan Ernst).

Supervisors are Prof. Sue Milton (Percy FitzPatrick Institute of African Ornithology – Department of Zoology – University of Cape Town), Prof. Timm Hoffman (Plant Conservation Unit – Department of Botany - University of Cape Town), Dr David Le Maitre (Council for Scientific and Industrial Research (CSIR)) and Prof. Theo Kleynhans (Stellenbosch University).

SITE 2: Restoration of the veld and hydrogeology in the Nama Karoo, Beaufort West

Research site

The research site is located in the heavily grazed and degraded Nama Karoo rangeland on two adjacent farms (Brandwagt and De Hoop) about 30 kilometres north of Beaufort West in the Western Cape.

The study site at Brandwagt farm.

Image: Thabisisani Ndhlovu

Description of the problem at the site

Invasion by alien plants is a major environmental and economic problem in the Nama Karoo. The worst of these is the mesquite (Prosopis species).

The concentration of mesquite around water points, combined with their deep root system, is thought to have reduced the availability of groundwater through both the interception of water in the upper soil levels as well as the deep roots tapping into the groundwater. This groundwater contributes to the water supply for the Karoo town of Beaufort West and so it is important to protect this resource. The sustainability of the meat- and wool-based small-stock industry of the area relies entirely on natural pasture and this industry is threatened by the erosion of natural capital base by mesquite infestations.

An alien plant stump after clearing.

Image: Thabisisani Ndhlovu

The hypothesis being investigated is that clearing the mesquite will raise the level of the groundwater and result in the unaided regeneration of natural rangeland vegetation cover and grazing capacity. The resultant restoration of rangeland natural capital is expected to increase the assurance of water supply to Beaufort West and lead to financial and economic gains for the farmer and the surrounding area.

Description of the restoration and outcomes

Clearing of Prosopis sp. by a Working for Water team on a farm in the arid Central Karoo has not yet shown positive benefits. Although the vegetation has changed following clearing to resemble un-invaded vegetation, its grazing value has not improved significantly as palatable plant species have not yet recolonised the cleared areas. It is recommended that, following Prosopis clearing, the area be reseeded with palatable plants and livestock and game be excluded from the treated site for a period of time to allow the palatable plants to establish. The effect of Prosopis removal on the water table is being investigated.

Who are the collaborators?

Students working on this site are Mr Thabisisani Ndlovu (ecologist), Ms Helenya Vlok (economist) and Mr Musiiwa Makumbe (hydrologist)

Collaborators are Brandwagt farm on which restoration was done in the Nama Karoo.

Supervisors of the students working on this site are Prof. Karen Esler (Department of Conservation Ecology & Entomology, Stellenbosch University), Prof. Martin de Wit (School of Public Management and Planning, Stellenbosch University ASSET Research) and Dr David Le Maitre (CSIR).

SITE 3: Rehabilitation after strip-mining: Exxaro Namakwa Sands mine

Area of research site

Exxaro Namakwa Sands mine, Brand-se-Baai.

Description of the problem at the site

Strip-mining completely disrupts natural ecosystems through the destruction of natural vegetation, resulting in large-scale changes in the natural topography, soil structure and chemistry. South African legislation requires mining companies to restore mined areas but the restoration process is complicated by abovementioned changes to the original environment which determined the structure and composition of floral and faunal communities. The harsh environment (extreme heat, strong winds and low rainfall) at Brand-se-Baai further hinders the restoration process.

This research aims to monitor the effectiveness of the restoration process. It will also determine if private (financial) benefits will exceed restoration costs. This will be gauged in the light of social benefits realised and the economic value of the quantifiable social benefits. The research will also investigate the possibility of establishing a market for the payment of ecosystem services.

Description of the restoration and outcomes

ENS's restoration goal is to 'rehabilitate and re-vegetate disturbed areas and establish a self-sustaining Strandveld vegetation cover in order to control dust generation, control wind and water erosion, as well as restore land capability'. In this way the grazing capacity of the restored land should be as close as possible to that prior to mining operations. Before the mining process starts, the topsoil is removed and either directly transported to an area that is currently being restored, or stockpiled until it can be used. The subsoil is then removed and undergoes various treatments in order to separate and concentrate the mineral content. The portion of the subsoil left after treatment, known as tailings, is transported to mined-out areas and bulldozed to recreate pre-mining contours. The topsoil is then replaced and spread, and rows of shade cloth are erected perpendicular to the prevailing wind direction to act as wind-breaks.

ENS implements four restoration techniques varying the topsoil replacement, seeding and plant translocation. Cuttings of various indigenous plant species are made from natural vegetation on nearby farms and allowed to grow in an on-site nursery. The seedlings are transplanted with the first winter rains. After five to six years the vegetation cover has established sufficiently for the wind-breaks to be removed.

Who are the collaborators?

Students involved in this research are Mr Worship Mugido (economist) and Mr Marco Pauw (ecologist).

The Namakwa Sands mine research area.

Image: Marco Pauw

The collaborator is Exxaro Namakwa Sands.

Supervisors of the students working on this site are Prof. Karen Esler (Department of Conservation Ecology and Entomology, Stellenbosch University), Prof. Theo Kleynhans (Department of Agricultural Economics, Stellenbosch University), and Dr David Le Maitre (CSIR). ▷▷

SITE 4: The Agulhas Plain

Table Mountain in the centre of the city of Cape Town. Image: Wikimedia commons

Table Mountain sandstone is a quartzitic sandstone, formed in the Ordovician (488-443 million years ago) era. This type of rock is highly resistant to erosion and forms the characteristic steep grey crags, seen particularly around Table Mountain in Cape Town.

Seed collecting at Bergplaas on the Agulhas Plain. Image: Mirijam Gaertner

Area of research site:

The area of the Agulhas Plain covered by this research is fynbos, which is growing on Table Mountain sandstone. The fynbos has been encroached by invasive alien plants, reducing the natural capital of the area.

Description of the problem at the site

Invasive vegetation has transformed much of the indigenous fynbos on the Agulhas Plain. Non-indigenous plants were originally planted with objectives such as dune stabilisation and shade provision. Some of these have become invasive and their rapid and persistent spread has led to the reduction in the natural capital of the area. This natural capital, such as fynbos flowers for export, is the source of ecosystem goods and services on which people depend. Land owners are reluctant to clear invasive vegetation for two reasons. One is the high costs incurred by such projects. The other is that if all land owners do not put equal effort into clearing then there will be reinvasion from uncleared areas.

The aim of the research at this site is to assess the change in the availability of water and the benefit of the restoration of natural capital after the removal of alien vegetation.

Description of the restoration and outcomes

Restoration on the Agulhas Plain was undertaken by removing different species of invasive vegetation and sowing indigenous fynbos seeds on plots on Table Mountain sandstone. Cost-benefit analyses are used to compare the present values of costs and benefits associated with natural capital restoration over a number of years. Financial analyses are undertaken to assess the impact of restoration on a farmer's production decision, while economic analyses are done to include costs and benefits external to a farmer. The outcome of this restoration is then extrapolated across invaded areas of Table Mountain sandstone for the whole of the plain.

Benefits associated with restoring invaded areas to indigenous wild fynbos include the sustainable harvest of fynbos flowers, the creation of employment through the use of marginal land, positive externalities such as beekeeping, thatching and Honeybush tea, and increases in water supply for agricultural and domestic use. The impact of restoration on carbon sequestration is being investigated.

Carbon sequestration is a technique for the long-term storage of carbon dioxide or other forms of carbon, for the mitigation of climate change. Planting vegetation that absorbs carbon dioxide is one approach.

The impact of restoration on ecotourism is expected to be small but positive. Other than the direct expenditure on restoration, costs include the opportunity cost incurred by the rural population who depend on invasive vegetation as a source of fuel for heating and cooking, and who derive income from firewood sales.

Who are the collaborators?

Students involved in this research site are Ms Helanya Vlok (economist) and Ms Megan Nowell (ecologist).

Collaborators in this research site are Flower Valley farm on which restoration was done on the Agulhas Plain and Flower Valley Conservation Trust and CIB (University of Stellenbosch).

Supervisors of the students working on this site are Prof. Martin de Wit (School of Public Management and Planning, University of Stellenbosch ASSET Research), Dr David Le Maitre (CSIR) and Prof. Karen Esler (Department of Conservation Ecology & Entomology, Stellenbosch University)

Conclusion

With an increasing scarcity of nature's services, it is expected that active restoration will play an increasingly important role in the future. Although the costs of active restoration are prohibitive in the context of abundant resources, it is expected that this situation is changing rapidly. Cheap land, water and biomass suitable for socio-economic development are becoming scarcer. The logical alternative is to restore what has been lost. □

Prof. James Blignaut, Dr Martin de Wit, Prof. Karen Esler, Dr David Le Maitre, Prof. Sue Milton, Dr Steve Mitchell and Ms Leandri van der Elst together with each of the students mentioned.

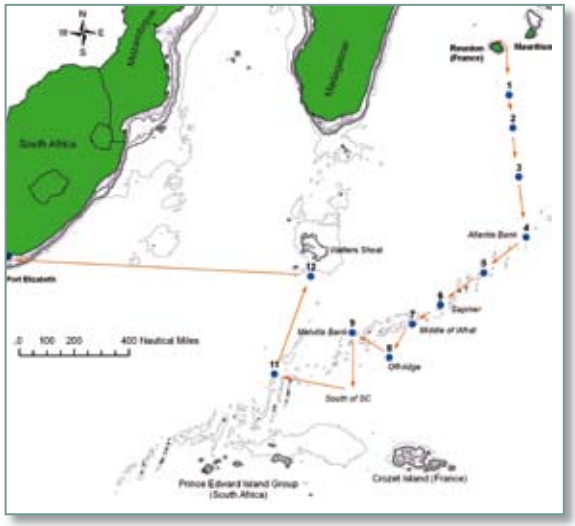
Understanding the ocean floor

A number of young South African scientists participated in a pioneering survey of the seamounts of the Indian Ocean that was carried out on the research ship *Dr Fridtjof Nansen* late last year. By **Sarah Gotheil** and **Claire Attwood**.

Above: The only octopus caught during the 40-day cruise was this unidentified species, caught on Walter's Shoal near Port Elizabeth. A surprising diversity of squids were caught, however and it is believed that some will be new to science. Image: Sarah Gotheil

Top left: A phyllosoma or rock lobster larva. Many seamounts host a large number of larvae because they seem to trap them. The transparency of the larva helps it to hide from predators. Image: Oddgeir Alvheim

Left: Beryx splendens *(Splendid Alfonsino), a deep-sea fish of commercial interest, which is typically caught at a depth of between 400 and 800 m.* Image: Oddgeir Alvheim



The research vessel Dr Fridtjof Nansen *left on 12 November from Réunion Island, and travelled 6 000 miles in 40 days to study five seamounts on the southwest Indian Ocean Ridge, and one seamount further north on Walters Shoal, south of Madagascar, before docking in Port Elizabeth, South Africa on 18 December.*

These young South African scientists worked side-by-side with a team of the world's leading experts and returned to South Africa with a rich collection of data and specimens, and a new understanding of seamount ecosystems. Seamounts are undersea mountains rising from the ocean floor. They are found in all the oceans of the world and are known to play an important role in ocean food webs.

The six-week survey of the seamounts of the Indian Ocean was organised by the International Union for Conservation of Nature (IUCN), in partnership with several other organisations, including the Agulhas and Somali Current Large Marine Ecosystems (ASCLME) Project and the African Coelacanth Ecosystem Programme. Both these multilateral programmes are based in South Africa and through their involvement in funding and organising the cruise, a handful of South Africans were asked to participate in the survey.

The overall goal of the survey was to improve knowledge of seamounts across the southwest Indian Ocean ridge. In pursuit of this goal, the team of scientists travelled 6 000 miles and returned to Port Elizabeth with nearly 7 000 specimens, ranging from two metre-long fish to tiny crustacean larvae.

The species collection includes an impressive variety of fish, shrimps, squids and gelatinous marine creatures. Many more samples of phytoplankton and zooplankton – representing the base of the ocean food chain – were also collected. Two seabird and marine mammal observers recorded thousands of seabirds from as many as 36 species, and 26 marine mammals over the course of the 40-day cruise. Two of them, majestic humpback whales, even offered the team a wonderful 30-minute display of breaching and spy hopping, only metres from the research ship.

'I am extremely pleased with the data that we have collected and the number of species that we have encountered', said Dr Alex David Rogers, chief scientist on the cruise and senior research fellow at the Zoological Society of London.

'The diversity of species that we sampled is higher than I would have expected. Some species have been recorded for the first time in the region, and we hope to have found some species new to science. It was also very interesting to discover that the six seamounts we surveyed are

The research ship, Dr Fridtjof Nansen*, provided a platform for a team of international scientists to survey the seamounts of the southwest Indian Ocean.* Image: Charine Collins

very different from each other, and I believe our findings will certainly improve our global knowledge of seamount ecosystems'.

A scientific workshop will soon be arranged to identify all the species collected, but the analysis of the thousands of samples collected on the voyage is expected to take many more years.

The results of the seamounts survey will not only have a scientific application, they will also help to improve conservation and management of Indian Ocean marine resources.

One of the primary goals of the survey is to confirm the conservation benefits of protecting seamount features on the ridge. This will inform future management of deep-sea ecosystems in the high seas on a global scale. □

Alex Rogers is a senior research fellow at the Zoological Society of London and was chief scientist on the seamounts research cruise.

Sarah Gotheil is programme officer with the IUCN's global marine programme.

Claire Attwood is a freelance journalist based in Cape Town. She works as media consultant to the Agulhas and Somali Current Large Marine Ecosystem (ASCLME) Project.

A feast for snot flower worms?

Are there any marine creatures with the wonderfully descriptive name of 'snot flower worm' living on the seamounts of the Indian Ocean?

This is the question that biologist Dr Kirsty Kemp, of the Zoological Society of London, is trying to find out. To tempt the little critters to reveal themselves, Dr Kemp delivered a few delectable whale bones and mango tree branches to the seabed of Atlantis and Coral seamounts. The bones and branches were attached to a transponder so that they can be located in 2011, when a second survey of the seamounts of the southern Indian Ocean is scheduled to take place.

Biologists know that whale carcasses are important mini ecosystems on the bottom of the sea. Each decomposition phase attracts different predators – the carcass mostly attracts bigger animals, while the bones are left to worms, bacteria and other tiny creatures. The unique community that colonises whale carcasses (and sometimes wood) is dominated by polychaete worms.

Dr Kemp is particularly interested in snot flower worms because they have been described in the Pacific Ocean, the North Atlantic and the North Sea but, so far, none have been described in the Indian Ocean.

Why are they called a snot flower worms?

'In water it looks like a flower, but out of water it looks like snot!', she says.

The snot flower worm

Why study seamounts?

By Alex David Rogers

Most of the deep sea is inhabited by a very sparse, but diverse, community of animals.

This is because most of them rely on particles of food raining down from the sea surface where photosynthesis takes place. As this food – known as marine snow – sinks, it gets consumed and only a small part reaches the seafloor.

Seamounts are different because some of them harbour striking communities of fish and other animals living on the seabed. They also appear to be hotspots for ocean predators such as sharks, tuna, whales, seabirds and seals.

One of the reasons we are studying the South West Indian Ocean Ridge is that the seamounts along it occur at a variety of depths and in different currents and provide us with a range of environments to try and understand what makes seamounts biological hotspots.

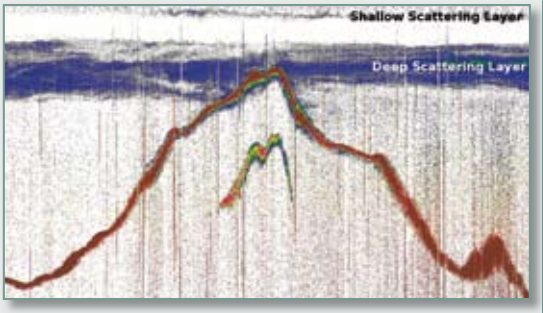
The other reason for studying seamounts is that fishers target seamounts for their abundant fish populations, including orange roughy, oreos and cardinal fish.

When exploitation of seamounts began there was very limited knowledge about the biology of the fish stocks that were being targeted. It turned out that many seamount fish stocks were extremely vulnerable to overfishing because they live for more than 100 years, grow extremely slowly and are very late to mature and reproduce. But, because many stocks were located in the high seas, where there was no control on fishing effort, they crashed very rapidly.

In addition, it was discovered that bottom trawling was highly destructive to seabed communities, which were formed by animals like corals on seamounts. Some of these have now been aged to more than 4 000 years old (although typical ages are tens to hundreds of years old), and are unlikely to recover from the impacts of fishing.

Thus we aim to identify why commercial stocks of fish are found on the South West Indian Ocean Ridge (and therefore elsewhere); how important the seamounts are to other marine life, including birds and whales; and to make our findings available to the fishing industry and managers of fisheries in the region, to help develop ecosystem-based precautionary management of high-seas seamount fisheries.

In 2011 we will return to the Indian Ocean to investigate whether vulnerable marine ecosystems, such as coral reefs, occur on the ridge.



A seamount echogram. The thick blue layer at the summit of the seamount represents the deep scattering layer (DSL). The DSL reflects sound and is visible on echosounders. The world's largest daily migration occurs in the DSL when animals rise to the sea surface at night to feed and then sink back into the dark depths by day to avoid being eaten themselves.

A life on the ocean wave

Riaan with the multinet.

Often working at night and in rough weather, the scientific team on the Dr Fridtjof Nansen *collected and preserved almost 7 000 specimens.*

An unusual looking fish, this Bean's sawtoothed eel was caught at 500 m.

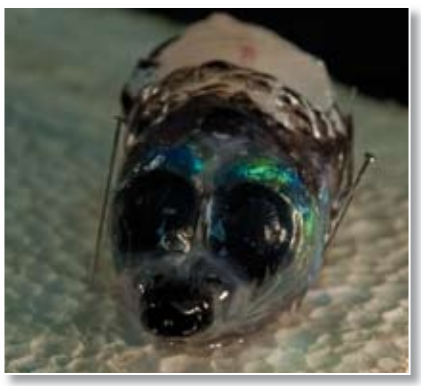
Caught at 500 m was this deep-sea angler fish, also known as a 'sea toad'. Image: Sarah Gotheil

Riaan Cedras was one of five South African scientists who participated in the survey of the seamounts of the southern Indian Ocean and writes about his experiences on the *Dr Fridtjof Nansen*, where he worked side-by-side with some of the leading marine scientists in the world.

On 11 November 2009 the engines of the *Nansen* started up and the international team of scientists on board prepared for departure from Réunion Island where our 40-day survey of the seamounts of the southwest Indian ocean was to begin.

As is the case on many scientific cruises, our plans were immediately complicated by equipment – or rather the lack of it. The British zooplankton team, which I had joined, was faced with a dilemma because the Methot net they had planned to use for sampling plankton was not on board the *Nansen*, but stuck at Heathrow Airport in London! This meant that a new zooplankton sampling protocol has to be drawn up from scratch.

Having sampled zooplankton from the *Nansen* in 2008, I was familiar with the ship's Multi-net and was able to share my experiences with the zooplankton team. I told them about its capabilities and limitations and some of the problems that might arise when we used the Multi-net. I think one of our biggest challenges was that the British team had planned to split zooplankton samples. This was difficult to do at sea and we needed a Folsom plankton splitter to split the samples accurately. We didn't have one on board, but I was able to build one and when I tested it, it worked very well, splitting the samples into two equal halves. I have to admit those guys were very impressed. It made me feel important throughout the cruise because I realised that there was nothing that the team would not ask me to help with.



One of the expedition's most exciting finds was this barrel eye fish which has huge eyes within a large, dome-shaped transparent or translucent head.

On the other hand, as I collected my own samples, there was always help at hand. I also watched in amazement at how genetic material was collected from each fish. The fish from each trawl were collected and placed in ice-cold water, which kept the DNA frozen and prevented it from denaturing. Furthermore, fascinating pictures were taken by Sarah Gotheil and Oddgeir Alvheim, by placing beautiful specimens such as cephalopod larvae into a fish tank filled with cold water to create buoyancy for the animal. As the animals slowly sank in the tank, the photographers snapped away.

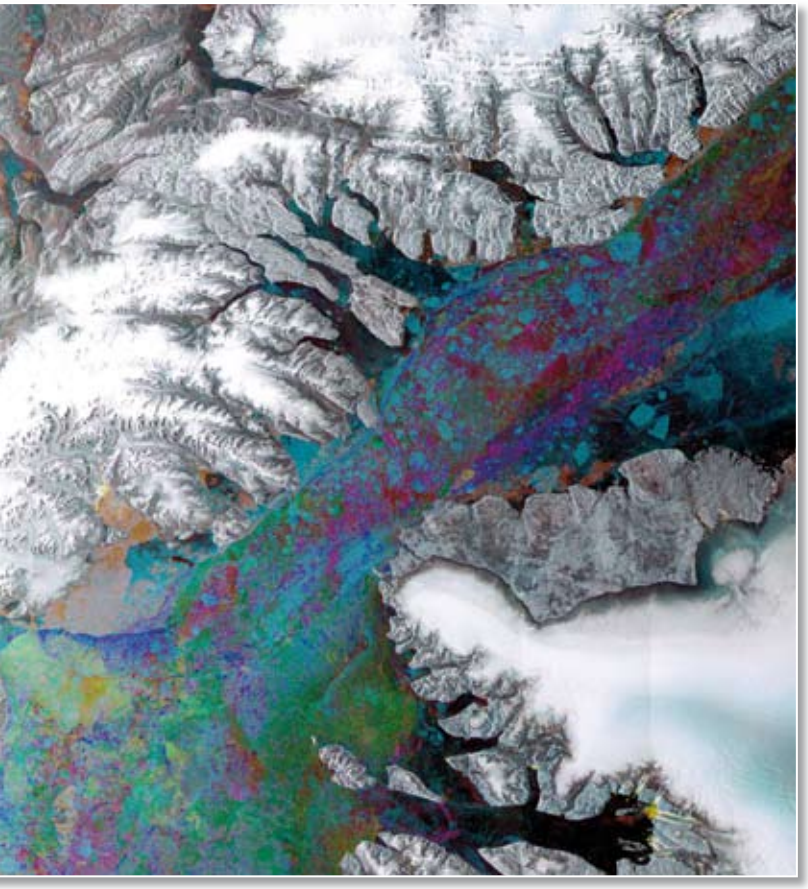
While we were on board, the crew kept us informed about weather conditions, such as strong winds and rough seas. These were a common occurrence over the 40-day cruise, but we were compensated with spectacular sights of whales jumping and seabirds diving.

Daily scientific meetings inspired me and taught me how to go about running a scientific cruise one day when I'm chief scientist. Alex Rogers, who was chief scientist on this cruise, was very time conscious, making sure that scientists were sampling and working when they were required to. No sloppy behaviour was tolerated and I learnt about the importance of working as a team.

A great deal of effort was put into organising and funding this survey of the seamounts of the south western Indian ocean and I am looking forward to participating in future workshops and publications related to the survey. □

Riaan Cedras recently completed his Masters' degree in Zoology at the University of the Western Cape. He will soon begin studying for a PhD that will identify and document plankton abundance and structure in the western Indian Ocean.

So you want to be a hydrologist?



A satellite image of the Arctic islands. Image: ESA

Megan Nowell, from the University of Stellenbosch ASSET Research, tells us what hydrology is and why she studies the subject.

When I tell people I am studying hydrology, I usually get a blank response. Hydrology? I might as well be speaking Greek. In fact, the word 'hydrology' really is Greek. It is derived from the words 'hydr' meaning water, and 'logos' meaning study, and that is exactly what hydrology is all about: the study of water.

The list of job areas a hydrologist can go into is not short. Hydrologists can study the quality, quantity and distribution of water resources. They may also look at the interaction water has with living organisms such as plants or insects, or what effect it has on the greater landscape. Ice caps, glaciers, clouds and weather forecasting also fall into the territory of a hydrologist. They work together with engineers to build dams and bridges, and with farmers to determine the best place for a borehole or how an irrigation scheme should be designed. Who do you call if there is a drought or a flood or a polar ice cap starts melting? Your friendly neighbourhood hydrologist.

Generally you would think of water in terms of what you put in a bottle for sport practice or perhaps of filling your swimming pool, but I can assure you there is a whole lot more to it. Let me give you some stats to really put this awesome and vital resource into perspective. In its liquid form, water dissolves more substances than any other liquid. It also composes around 70% of your body and covers close to 75% of the Earth's surface. Twelve percent of this is snow cover or ice and if you can believe it, this accounts for nearly 80% of our freshwater supply. South Africa is classified as a semi-arid country, which

Above left: A dam showing its catchment areas in the surrounding mountains. Image: Megan Nowell

Above: A wetland area. Image: ESA

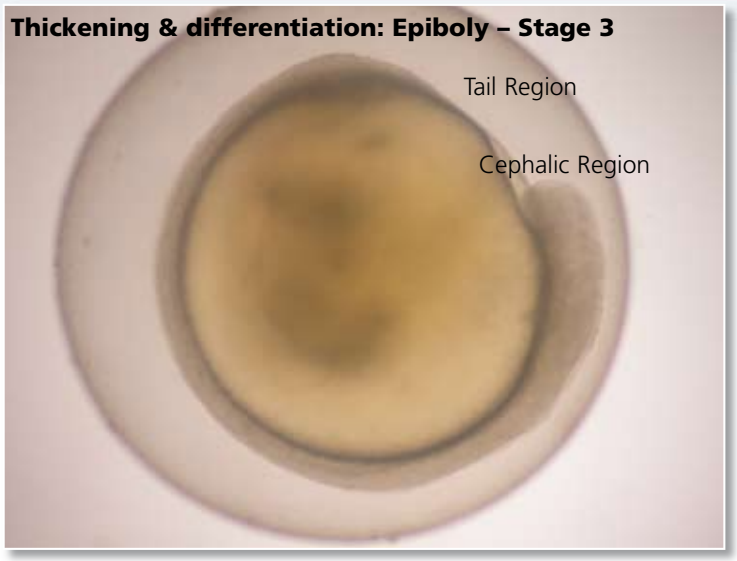
means we have to watch every drop. In fact, South Africa has one of the lowest rainfall to runoff ratios in the world. I haven't even begun to talk about clouds and soil moisture, but there is one last fact I want to leave you with. A single drop of water can take thousands of years from when it travels down through the soil to the groundwater, until it reaches the end of its journey. And that is why the main job of a hydrologist is to ensure that our hydrological cycle continues to flow undisturbed for generations to come.

Because there are so many different aspects of hydrology, there are different branches too. The most common branches are chemical hydrology (the chemical components of water), ecohydrology (the interaction between water and living organisms), hydrogeology (the study of groundwater and its interaction with geological components), surface hydrology (as the name suggests, it looks at the hydrology of surface water), hydroinformatics (although the name sounds scary, this is using information technology to model and monitor water resources) and hydrometeology (the transfer of water and energy from one state to another and then back again).

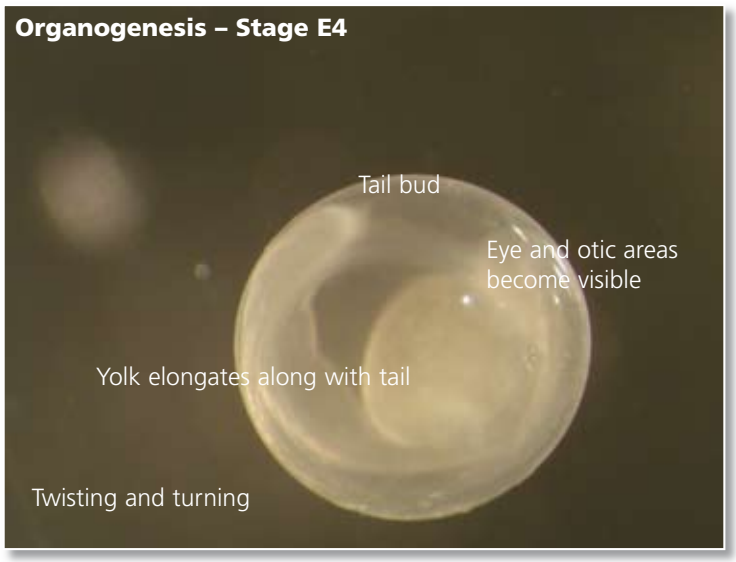
Sound interesting? Hydrologists can have a background in ecology, environmental science, geology, geography, or civil and environmental engineering depending on what you would like to specialise in. As the Hungarian biochemist and Nobel Prize winner, Albert Szent-Gyorgyi once famously said, 'Water is life's mater and matrix, mother and medium. There is no life without water.' □

The birth of a fish

Daksha Naran shows us just how fascinating this natural process can be.



The stage of thickening and differentiation in which the head and tail start to form. Image: Daksha Naran



The stage at which organs start to form. Image: Daksha Naran

Watching and observing a young larval fish emerge from its egg is a fascinating process. I recently undertook an artificial breeding experiment that allowed me to examine the birth of a fish very closely.

The experiment took place at the Gariep Dam State Hatchery, on the Gariep Dam, Free State. A few weeks before we arrived at the hatchery the male and female fish were moved to a special conditioning pond. The move was important because the fish, in this case an indigenous yellowfish, *Labeobarbus aeneus*, reproduce during the spring to summer months.

In order to ensure that our experiment was successful we wanted to create an environment where there was a good chance that the fish would redirect and focus their energy into reproduction. That way, when we arrived at the hatchery, we could collect the reproductively mature fish and they would be ready to release their eggs and sperm.

Priming for reproduction

When we arrived at Gariep Dam in early December 2008 we caught several male and female fish and kept them in a portable plastic pool. The selected fish were gently injected with a hormone, which helps the maturation and release of the gonads (eggs and sperm). It takes a few hours for the hormone to take effect.

Yellowfish, under natural conditions, spawn in early summer (October), with sporadic breeding continuing until March. Male and female fish congregate at spawning sites which are usually shallow gravel beds. Female fish that are ripe and ready to spawn start the spawning process by swimming past ripe running males. Several males and females congregate, and you can see when spawning takes place by the splashing water. This happens as the eggs and sperm (called milt in male fish) are released into the water.

Handling fish under these experimental conditions requires delicacy and experience, so that the fish are not damaged or upset.

Male and female fish were separately 'stripped' for egg and sperm. This involves taking the fish out of water for a short period and gently but firmly pressing the abdomen so that the eggs and sperm ooze out of a pore. These are collected and gently mixed (artificially fertilised) and then incubated in an aquarium. The fertilised eggs, now called embryos, are suspended on a fine meshed tray to ensure that they are well aerated.

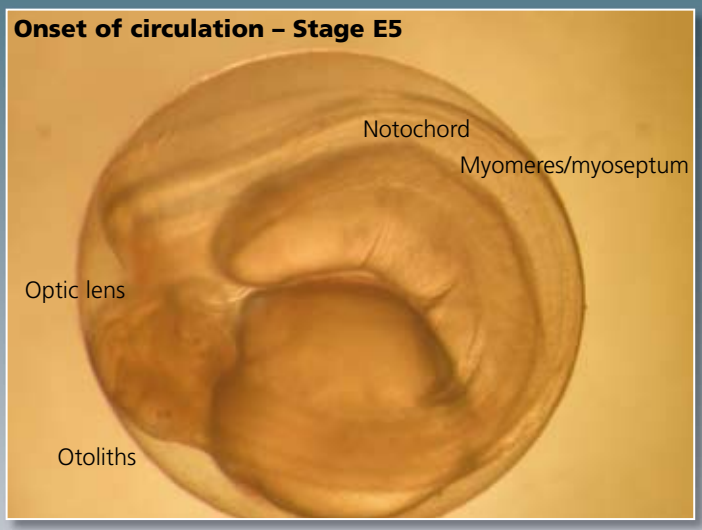
The birth of a fish

As we observe the developing embryo the fascinating journey begins to unfold. We tracked the development of the embryos by photographing them.

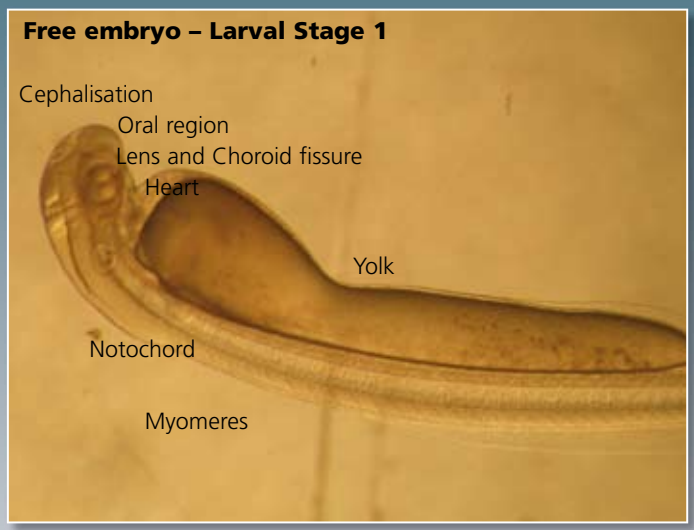
There are five key stages in the embryo period: activation, cleavage, epiboly, organogenesis, onset of blood circulation These steps are called E1 to E5. The time from fertilisation to hatching lasted between three to six days.

Stage E1, activation: After activation the eggs begin to take in water and increase in size. They become sticky and stick to each other and to the hatching tray. Under natural conditions the newly fertilised eggs would attach themselves to gravel, rock surfaces and leaves – an adaptation to secure themselves in flowing waters. Activation is a stage that occurs only under experimental conditions as the eggs and milt are manipulated outside of the water environment.

Stage E2, cleavage phase: This marks the period during which cell division occurs, beginning with a two-cell egg and ending in a blastula stage in which there are many undifferentiated cells dividing. These cells are all alike, but are at a unique stage during which they all have the potential to specialise for a particular function.



The onset of circulation. Image: Daksha Naran



The free embryo in its first larval stage. You can see that the features on the larva are quite different from those of an adult fish. Image: Daksha Naran

Blastula: this is an early stage of embryonic development in animals, which is produced by the cleavage of a fertilised ovum. The blastula consists of around 128 cells that occur around a large fluid-filled space called the blastocoel.

Stage E3, epiboly: This starts with the cell layer migrating across the yolk surface and forming an embryonic shield, which surrounds the circumference of the yolk. The cell layer covers about three-quarters of the yolk surface. As the cells grow and divide they encircle the entire yolk. You can see a clear head area, which has a thicker mass of cells and a tail area with a thinner layer of cells. This stage is marked as the closure of the germ, and takes place at about 31-40 hours after fertilisation.

Stage E4, organogenesis: This is a complex stage where major organs begins to emerge, such as the neural plate and head (cephalisation) of the embryos. At this stage the initial stage of the (eye) optic vesicle becomes evident in many of the embryos. Muscle bands or myomeres become visible. The notochord is visible.

At this stage the tail section also starts to separate from the yolk. This causes the yolk to become elongated, and it is slender along the lower part of the embryo and more rounded at the anterior end.

Notochord: this is a flexible, rod-like body that is found in the embryo of all vertebrates. In most vertebrates it is replaced by the bony vertebral column in the adult animal.

Stage E5, blood circulation: The onset of blood circulation begins with the start of muscular contractions. The stage ends with the embryo hatching. In the head region the brain is visible, the eye pigment can be seen and the beginning of the otic vesicles becomes apparent. The rudimentary buds of the pectoral fins can also be seen at this stage. Earbones, called otoliths, which are used for fish ageing, become visible and the blood begins to look red. The embryo is mobile and twists and turns vigorously under the light of the microscope.

Otoliths are small particles that are sensitive to gravity. Their function is similar to that of our inner ear in sensing changes in body position and movement.

Larva stage 1: A newly hatched embryo, now called a larva, is the next development stage. The yellowfish larva has developed muscle bands (myomeres), still uses the remaining yolk reserves, and is able to wriggle on the bottom surface for short periods.

This series of photographs marks the end of the embryo stages. □

Daksha Naran holds an MSc in Ichthyology from Rhodes University. She has been a guest lecturer at Rhodes University in the Department of Ichthyology and Fisheries Science, and at the Environmental Science, and was also a research assistant for three years at the South African Institute for Aquatic Biodiversity, where she gained extensive experience in freshwater ichthyology. She has been involved in coordinating a student mentoring programme for Rhodes University, and is a Project Manager for the bioregional CAPE conservation education programme. She has participated in several research projects, building expertise in molecular genetics, population biology, biodiversity conservation education and academic development. More recently, her research involvement has been in the fields of early development and biodiversity. She has several scientific and popular publications to her name.

Mercury exposure –

Mamopeli Matooane and colleagues from the CSIR speaks about mercury in our environment: just how much mercury is there and what are the health risks?

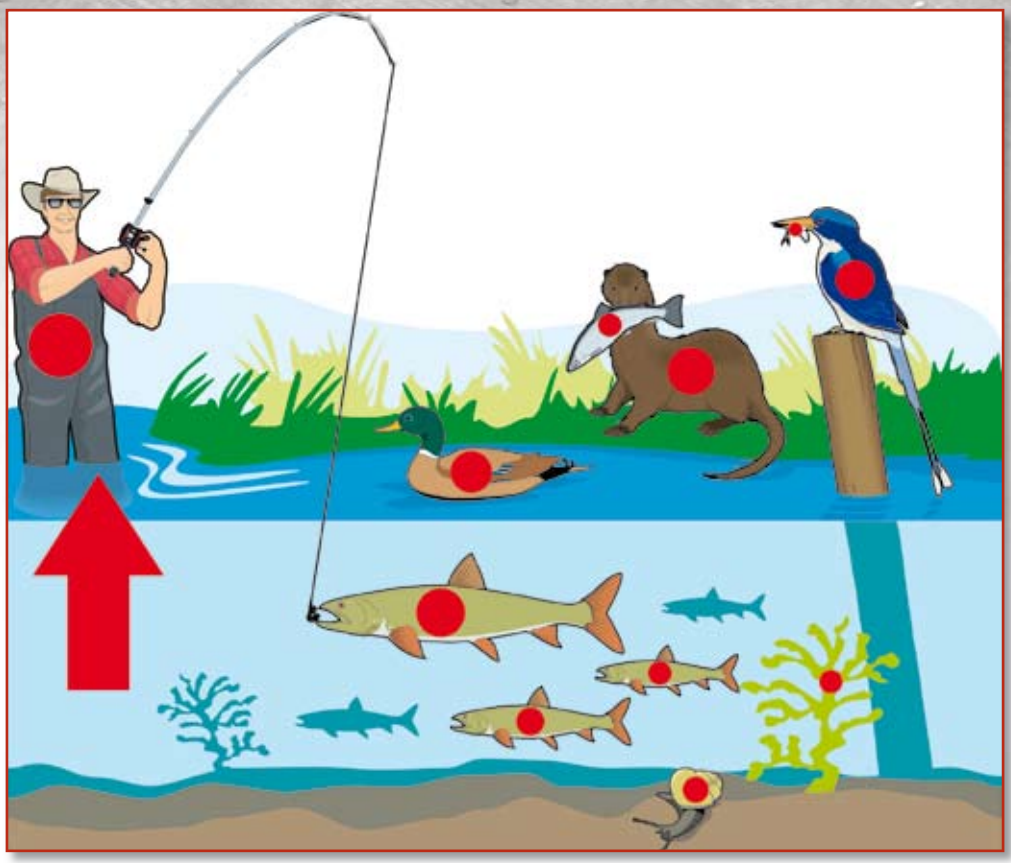


Figure 2: Bioaccumulation of methyl mercury (Environment Canada, 2004).

Table 1: Results from recent studies on mercury concentrations in air, fish and humans in the South African environment.

Media	Study	Mercury concentrations	Reference
Air	Emissions from coal-fired power plants	9.8 tons per year	Dabrowski *et al.*, 2008
	Concentrations for a 1-hour average period	0.0387 µg/m^3	Carter and Raghunandan, 2009
	Concentrations for a 24-hour average period	0.003 µg/m^3	Carter and Raghunandan, 2009
Water	Freshwater mercury concentrations	Below detection limit – 0.96 ng/ l	Binedell *et al.*, 2008
Fish	Health risk assessment	0.05 to 0.66 µg/g wet weight (ww)	Oosthuizen and Ehrlich, 2001
	Health risk assessment	0.010 - 0.498 µg/g ww	Binedell *et al.*, 2008
	Health risk assessment	0.014 to 0.486 µg/g ww	Matooane *et al.*, 2009
Humans	Blood/urine (occupational exposure)	1.05 -2.28 µg/l of creatinine	Kaeteva *et al.*, 2008
	Maternal and umbilical cord blood	Median = 1.78 µg/l (0.44 - 8.82 µg/l)	Rollin *et al.*, 2009

Where does mercury come from?

Mercury (Hg) (Figure 1) is ubiquitous in the environment and can thus be found in all environmental compartments. It exists in different chemical forms in the environment, namely elemental or metallic Hg (Hg^O), inorganic Hg ($Hg2^+$) and organic mercury Hg (MeHg). South Africa is considered one of the major contributors to global Hg emissions into the atmosphere, mainly due to coal-based power generation. Estimates suggest that stationary sources emit approximately 50 tons per year (Pacyna *et al.*, 2006). However, there is evidence to the contrary suggesting that South Africa's Hg emissions from stationary sources are 10 times less than previously reported (Dabrowski *et al.*, 2008).

While the debate is ongoing, Hg is released from various sources and is present in air, soil, water and biota in the South African environment and those exposed are potentially at risk of developing adverse health effects.

How can we be exposed to mercury?

Exposure to Hg occurs through the inhalation of Hg vapours, or ingestion of Hg-contaminated food or water. Mercury can also enter the body through the skin (dermal contact). However, the ingestion of Hg-contaminated food (particularly fish) remains the principal exposure route (WHO, 2003; Jiang *et al.*, 2010).

In biological systems, inorganic Hg is transformed by microbial activity through a process known as methylation to produce organic Hg (e.g. methylmercury, MeHg), the more toxic form of Hg. MeHg is lipophilic (absorbed in the body fat), a property that allows it to bioaccumulate and biomagnify in biota. Therefore, people who regularly eat fish (such as subsistence fishermen) which may be contaminated with MeHg, are potentially at risk of developing adverse health effects associated with Hg. Fish that often contain elevated levels of MeHg are predatory fish such as tuna, kob and largemouth bass.

are we at risk?

The Periodic Table of the Elements

1 H Hydrogen 1.00794																	2 He Helium 4.003
3 Li Lithium 6.941	4 Be Beryllium 9.012182											5 B Boron 10.811	6 C Carbon 12.0107	7 N Nitrogen 14.00674	8 O Oxygen 15.9994	9 F Fluorine 18.9984032	10 Ne Neon 20.1797
11 Na Sodium 22.989770	12 Mg Magnesium 24.3050											13 Al Aluminum 26.981538	14 Si Silicon 28.0855	15 P Phosphorus 30.973761	16 S Sulfur 32.066	17 Cl Chlorine 35.4527	18 Ar Argon 39.948
19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.955910	22 Ti Titanium 47.867	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938049	26 Fe Iron 55.845	27 Co Cobalt 58.933200	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.723	32 Ge Germanium 72.61	33 As Arsenic 74.92160	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.90550	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.90447	54 Xe Xenon 131.29
55 Cs Cesium 132.90545	56 Ba Barium 137.327	57 La Lanthanum 138.9055	72 Hf Hafnium 178.49	73 Ta Tantalum 180.9479	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.078	79 Au Gold 196.96655	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98038	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
87 Fr Francium (223)	88 Ra Radium (226)	89 Ac Actinium (227)	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (263)	107 Bh Bohrium (262)	108 Hs Hassium (265)	109 Mt Meitnerium (266)	110 (269)	111 (272)	112 (277)	113	114				

58 Ce Cerium 140.116	59 Pr Prasodymium 140.90765	60 Nd Neodymium 144.24	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92534	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93032	68 Er Erbium 167.26	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967
90 Th Thorium 232.0381	91 Pa Protactinium 231.03588	92 U Uranium 238.0289	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)

Figure 1: Periodic table of elements; After UWSC, 2009.

However, Hg concentrations have also been found to vary not only by the dietary habits of fish but with species age and size, and location as well (Environment Canada, 2004).

In addition to subsistence fishermen, fetuses and children are especially vulnerable to Hg exposure due to their incomplete physiological development. Therefore pregnant women should avoid occupations in Hg-amalgamation, gold mining, chlor-alkali chemical industries and other industrial activities involving Hg handling, which are likely to greatly enhance Hg exposure (Mahaffey *et al*., 2008; Kataeva *et al*., 2008; Jiang *et al*., 2010).

What are the health effects of mercury exposure?

Once Hg enters the body it can be transported to various organs through the circulatory system. Adverse health effects associated with Hg exposure include mental retardation, cerebral palsy, deafness and blindness and effects on the central nervous system. In pregnant women, Hg can negatively affect the development of the fetus. It is also highly toxic to the brain and kidneys (WHO, 2003). The magnitude of effects is dependent on the concentration or dose received. Guidelines or reference values are often used to ascertain whether Hg exposure is excessive or negligible.

The South African reference guidelines, used by pathologists, for people exposed to mercury in the environment (excluding workplaces), are:

- Less than 5.0 µg/g of creatinine in urine
- Less than 10.0 µg/l in blood

What do we know so far about how much mercury exists in our environment?

There are very few data for Hg concentrations in the South African environment. However, some studies have tried to understand more about Hg emissions into the atmosphere, concentrations in water and biota, and potential impacts on both the environment and human health. Results for studies of Hg concentrations and exposures in South Africa are shown in Table 1.

Health impacts of mercury exposure

Few studies have investigated the human health impacts of Hg in South Africa, and those that there are have focused on subsistence fishermen. A risk assessment was undertaken by ▹▹

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combining data on Hg concentrations in fish commonly eaten by fishermen, and population data (consumption rate and body weight) to estimate potential risk. Results from these studies indicated that subsistence fishermen were at risk of developing adverse health effects due to Hg exposure.

Health risk was dependent on the species of fish consumed and location where fish was caught.

- Fish data for the Mvoti-Umzimkulu Water Management Area (WMA) showed increased risk for all types of individuals living there and eating certain types of fish (Oosthuizen and Erlhich, 2001).
- People eating one fish meal per day of large-mouth bass found in the Steenskoolspruit River in Mpumalanga, were also shown to be at risk of high mercury effects (Binedell *et al*., 2008).
- Another study also showed a risk for people who ate yellowfish found in the Kaap River in the Inkomati WMA and red-breasted tilapia, banded tilapia and catfish found in the Mngceweni River in the Mvoti-Umzimkulu WMA (Matooane *et al*., 2009).
- Risk estimates for eating saltwater fish (found in the ocean) were also high for red roman, red panga and silverfish collected in the Western Cape (Matooane *et al*., 2009).
- Lastly, red roman obtained from subsistence fishermen at the Durban harbour resulted in elevated risks for people eating this fish species (Matooane *et al*., 2009).

These results suggest that people who regularly eat locally caught fish with elevated Hg concentrations, may be at risk.

A call for action

Mercury occurs in the South African environment, sometimes at concentrations above guideline values for human health protection, particularly sensitive individuals. People who regularly eat locally caught fish with elevated Hg concentrations are potentially at risk. However, there are no South African consumption guidelines based on the status of Hg pollution and Hg concentrations in fish to guide local consumers.

This is reason for serious concern, especially for individuals who eat fish more frequently. Since data are sparse, more studies are needed to better calculate risk. Researchers should collaborate and work with other national institutions and government organisations to address this serious health issue. □

Mamopeli Matooane is an environmental health scientist at the Council for Scientific and Industrial Research (CSIR). She is based within the Natural Resources and the Environment (NRE) Division. She holds an MSc with majors in environmental sciences from the University of Natal. Her research interests include human health risk assessment, air pollution, time-activity patterns, and climate change and human health. She has over 7 year's experience as an environmental health researcher, working on research and consulting projects focusing on air quality specialist studies for environmental impact assessments (EIAs), air toxics monitoring and mercury risk assessment studies. Mamopeli has authored and co-authored several peer-reviewed journal and conference papers, and technical reports.

Vernon S. Somerset received his PhD degree in analytical chemistry (2007) from the University of the Western Cape (UWC), Bellville, South Africa. He is a senior researcher in the Natural Resources and the Environment (NRE) department at the Council for Scientific and Industrial Research (CSIR), South Africa.

Chavon R. Williams is currently completing her MSc (Earth Sciences) at the University of the Western Cape, Bellville, South Africa. She is a researcher in the Natural Resources and the Environment (NRE) competency area at the Council for Scientific and Industrial Research (CSIR), Stellenbosch, South Africa. Chavon is the author and co-author of several papers in peer-reviewed journals, technical reports and conference proceedings.

The science of home truths

Ntombi Cindi (pictured) is a 16 year old Grade 11 learner from Lentegeur in Cape Town with aspirations of becoming a scientist, a career she was first exposed to at a Science Expo.

Her interest in the sciences was ignited when her school, Lentegeur High became part of the Zenex-Spark Project. The project pioneered the formation of Science Clubs driven by teachers and learners. However, in schools characterised by a lack of resources, the only equipment available to the budding scientists, for conducting experiments are basic household materials.

In the spirit of scientific exploration, Coke bottles, water buckets, matches and candles are some of the apparatus they use to bring home some scientific truths.

It is from these humble beginnings that the best projects were chosen to display at the regional ESKOM Young Scientists Expo in Stellenbosch in 2009. Eighty eight learners from the project schools took part in the Expo, winning two bronze and two silver medals in the process. This was their ticket to the National Expo in October 2009 in Pretoria, at which over 800 learners from schools across the country displayed their experiments.

Confident that practise makes perfect, facing off against learners from some of the most resourced schools in the country was no deterrent for Ntombi. Her scientific investigation into the different household solutions used in townships to test for pregnancy earned her a silver medal.

Science Clubs and Expos spark interest in science

'It was in the Science Clubs that we discussed aspects of everyday life that we wanted to know more about. We also held mock expos in our schools, to demonstrate practical science to our peers and communities', says Ntombi.

Science Clubs and Expos have proven to be the right formula for making science come alive and overcoming the fear with which most learners approach the subject. It is at these platforms that learners are encouraged to learn through practise, a critical aspect for understanding the basics of science.

The Zenex Foundation is challenging learners to start grappling with the fundamentals of science in the most basic ways possible. This is in line with the organisation's strategic goal of increasing uptake and performance in science in high schools. This might just be the key to unlocking learner potential in science to reverse the underperformance marked by a 37% pass rate in matric science in 2009.

It is not rocket science!

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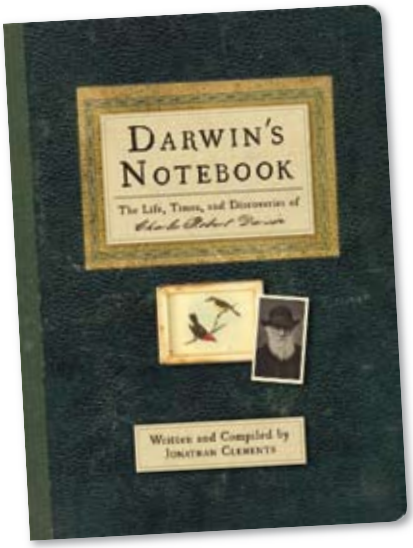


Insight into the man

Darwin's Notebook: The Life, Times and Discoveries of Charles Robert Darwin. Written and compiled by Jonathan Clements. (Cape Town. Zebra Press. 2009)

Last year saw many books about Darwin and many reprints of his work. Most of us have read – or at least dipped into – the famous *Origin of Species* and I am reading his notes on the voyage of *The Beagle* at the moment. Both of these major works give quite a lot of insight into Darwin, the man – very much a product of his time, albeit with revolutionary ideas about the origins of life.

However, this little volume provides another side of Darwin. It is a compilation of material from Darwin's own notebooks and diaries and an account of his life as well. Starting with information about Darwin's family – his own origins – the account takes us through his early life, his school and university career and on to his life-changing world voyage.

The early material is illuminating. Darwin was not happy at school and a poor student (probably bored!), but his interest in science persuaded his father to send him to medical school. Here he neglected his studies, something he apparently later regretted. However, he did learn taxidermy, in his words 'from a blackamore … he only charges one guinea, for an hour every day for two months'.

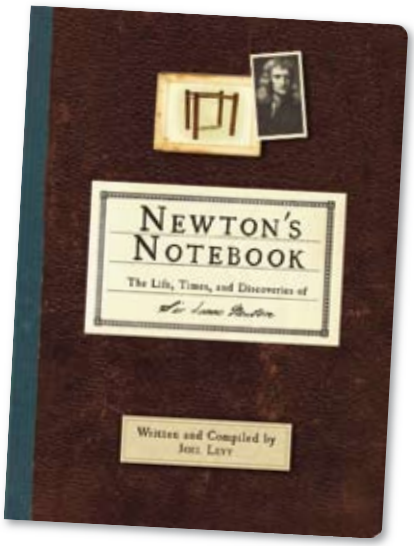
When Darwin failed medicine, his father decided he should do an 'honest degree' and become a country parson. One of the charming features of this book are quotes from Darwin himself. 'I did not then in the least doubt the strict and literal truth of every word in the bible.' Then later, 'Considering how fiercely I have been attacked by the orthodox, it seems ludicrous that I once intended to be a clergyman'.

Cambridge, however, was another story. 'The three years which I spent at Cambridge were the most joyful in my happy life.' The book continues with the chronicle of Darwin's life – splitting the voyage on *The Beagle* into easy-to-digest sections, each of which pulls out the most important details of the area visited.

While Darwin is best known for *Origins* and his *Beagle* notebooks, he was a dedicated scientist and prolific writer. These later writings make for fascinating reading – *The Descent of Man, and Selection in Relation to Sex* was published in 1871. The book expanded on his early theories, including that of sexual selection, 'We must remember that many parrots are ornamented with crimson, blue and orange, which can hardly be protective'. The last three chapters of this book are a fascinating study of the Victorian attitudes of the time towards savagery and civilisation – not in the least PC!

A particularly useful aspect of the book is the final section on Darwin's long-term legacy. It has been said that Darwin's (and to be fair, Wallace's) theory of evolution changed biology into a science. The author examines a hypothetical 'World without Darwin', looking at Lamarkism and Saltationism, an approach in which biologists believed that nature made 'massive leaps, through mutations brought on by cosmic rays and other influences'. Darwin's influence on the examination of the fossil record and how this relates to our understanding of human evolution is explored, as is the thorny issue of social Darwinism, which unfortunately led down the road to theories of racial superiority and eugenics, ignoring the fact that Darwin emphasised the similarities between human races, not the differences. The book finishes with the selfish gene – a brief introduction to molecular genetics and the discovery of DNA.

As a potted biography of one of the greatest biologists ever, this book is invaluable and a joy to read.



The falling apple

Newton's Notebook: The Life, Times and Discoveries of Sir Isaac Newton. Written and compiled by Joel Levy. (Cape Town. Zebra Press. 2009)

This is another in the Notebook series and equally fascinating and useful. Sir Isaac Newton is best known for his theory of gravity, which supposedly came to him while sitting under an apple tree.

The son of a farmer, Newton was an immensely complex man. He was a scientific genius, of that there is no doubt, but he also dabbled in alchemy, the occult and was convinced of the Second Coming. His personal life was also deeply troubled. He hated dispute – a strange trait in a scientist, he bore many grudges, struggled with his sexuality and 'flirted with madness'.

He was also born into an era of great civil, religious and intellectual turmoil, on Christmas Day, 1642.

Continuing the trend in the series, this book is filled with quotes from the great man. '1. If a quantity once move it will never rest unless hindered by some externall caus [sic]. 2. A quantity will always move on in the same streight [sic] line (not changing to determination nor celerity of its motion) unless some externall cause divert it.' These two axioms would later form the basis of Newton's first law of motion, also referred to as the law of inertia.

At school, Newton was referred to as 'a sober, silent, thinking lad'. Science as such was not taught, but Levy recounts how Newton had a talent for making things, mixing remedies, pigments and potions – which all added up to early indications of his genius. He also started experimentation. The day that Oliver Cromwell died, Britain was hit by an immense storm. Newton tried to estimate the strength of the wind by leaping into the air, first with the wind and then against it. He noted the distances between takeoff and landing and compared them to similar leaps he had made on a calm day. This allowed him to measure what he called 'the force of the storm'. He told his schoolmates that the storm was a foot stronger than any he had previously experienced!

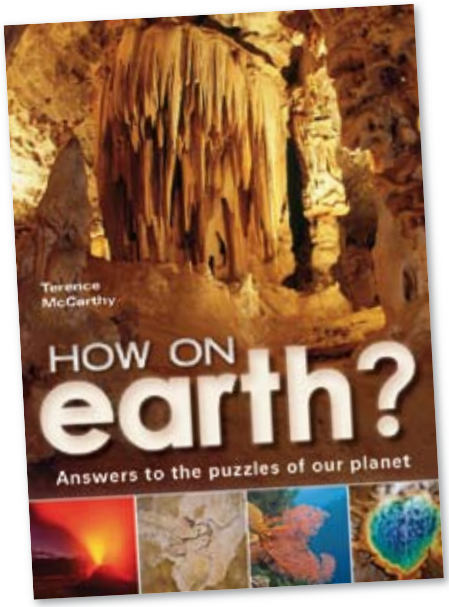
His early notebooks already show his interest in science and mathematics. One such example is instructions on exactly how to make a sundial. But for all this, along with another well-known scientific genius Albert Einstein, Newton did not excel at school until towards the end of his school career. He was then accepted into Cambridge, where he was admitted to Trinity College – starting what Levy describes as 'perhaps the greatest undergraduate career of all time'.

His solitary nature meant that he was a quiet undergraduate who attracted no attention. Levy points out that the curriculum of the time was outdated and uninspiring, but Newton found his insipiration in the contents of the great library of Trinity, and came into contact with a small number of forward thinking scholars. His first steps in science were questions – put down in his notebook – 'Certain philosophical questions'. He posed questions about the nature of matter, the theories of Descartes, who believed that all space was filled with matter and who also formulated a model that Newton thought

might explain the motion of the planets. He also started to think about the forces that could, for example, make a cannon ball travel through the air – gravity.

Levy, however, does not dwell entirely on Newton's theories around mechanics, but also reminds us that he made some major observations on light and the science of optics. The book beautifully explores the development of Newton's intellect and how his theories were formulated, but also shows Newton's fascination with the less scientific ideas of alchemy and mystical forces.

Newton died at the age of 84 and was intellectually active to the end. This book provides a concise and readable account of Newton's legacy, which was to tranform science and the way that science was seen.



Answers to puzzles

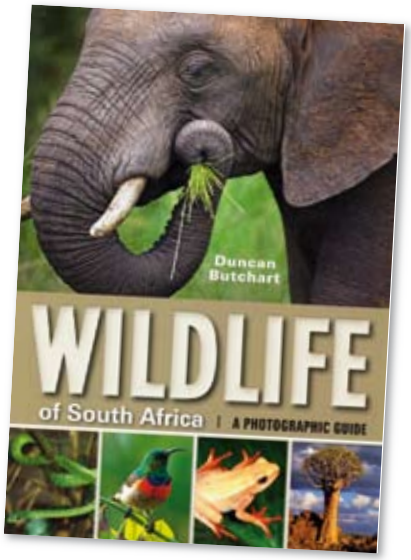
How on Earth? Answers to the Puzzles of our Planet. By Terence McCarthy. (Johannesburg. Struik Nature. 2009)

This book is a triumph and should do much towards stimulating an interest in science among young and old alike. The puzzles are set in different aspects of 'earth' – the Earth and its environment, Earth's changing face, the atmosphere and oceans, minerals, the world around us and life.

The questions it answers are, for example, what is the Sun made of? Why is seawater salty? What is the Sixth Extinction? Why is Table Mountain flat? How do gold nuggets form?

It is richly illustrated with photographs and colour diagrams and would be invaluable in any classroom, covering physical and life sciences, as well as geography.

There is a comprehensive glossary and a good index – both of which make the book particularly user-friendly. A must-have for any curious person.



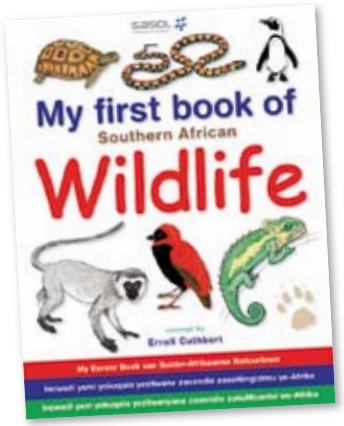
Photographing wildlife

Wildlife of South Africa: A Photographic Guide. By Duncan Butchart. (Cape Town. Struik Nature. 2009)

This lovely little book is a photographic field guide to South Africa's plants and animals. It starts with an introduction to the geography and climate of the region, along with notes on how to identify wildlife. There is a useful summary of the different vegetation zones and the wildlife that is likely to occur in each of them, essentially the major biomes, along with a brief discussion of conservation and its importance.

The sections of the book cover mammals, birds, reptiles, frogs, trees and shrubs. Each species covered is illustrated with a clear photograph, along with a distribution map and a brief description, which includes the habitat, average dimensions and the species' status.

Its size makes it an ideal companion on a motor trip, or even a hike in the countryside.



Catching them young

My First Book of Southern African Wildlife. Concept by Erroll Cuthbert. (Cape Town. Struik Nature. 2009)

This book is a combination of three My First Book of titles: *Southern African Birds* (2006), *Southern African Snakes and Other Reptiles* (2007) and *Southern African Mammals* (2008).

This series is an excellent introduction to our wildlife, in an easy to read format, with lovely illustrations and an easy to understand way of showing characteristics of the animal involved, such as a sun symbol to show an animal that is active in daylight, for example.

Again, as with all the books in the series, the text is in English, Afrikaans, Zulu and Xhosa. It should be on the shelves of all school libraries and in the book cases of all children fortunate enough to own their own books.

A fascinating landscape

A Landscape of Insects and Other Invertebrates. By Duncan Neil Macfayden, with photographs by Shem Compion. (Johannesburg. Jacana Media. 2009)

This was a wonderful book to receive as a reviewer! South African publishers have a tradition of producing coffee table books that are full of more than just lovely photographs. The book is dedicated to Strilli Oppenheimer for her work on the conservation of invertebrates.

We generally don't look out for invertebrates – other than with annoyance or fear in the case of the arachnids! But this book should change that. It is 'intended to introduce readers to the great beauty, diversity and ecological importance of South African insects'. These are covered in an area known as the Diamond Route – a range of nine properties scattered across South Africa that are owned by De Beers and the Oppenheimer family and which exist mainly to promote conservation and research.

The invertebrates in the book were found in a range of habitat types including mopane woodland, riverine forest, bankenveld grasslands and the Kalahari. Each landscape is covered separately, with an introduction to the landscape, geography, climate and vegetation of the region. The outstanding photographs of each species are complemented by detailed text, describing the organism in detail, along with information about its life cycle and life style.

There is also a glossary so that those who are not familiar with the biological terms used in invertebrates can understand the text. This book will not sit on a coffee table, but on the bookshelves of any serious biologist or anyone interested in the complete range of wildlife in South Africa.

Shows and exhibitions

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Especially for children aged 5–12

Davy Dragon's Guide to the Night Sky

Come and join Davy Dragon while he learns all about the sky above so that he can fulfil his dream of becoming the world's best flying dragon! This is a playful introduction to astronomy especially for the under 10s. Just right for inquiring young minds.
17 April – 6 June • Saturday – 12:00 • Sunday – 12:00 • 27 March – 12:00
Especially for children aged 5–10

Silly Solly and the Shooting Stars

Solly Snail wants to be chosen for his garden's soccer team and thinks up ways to become a speedier snail, so that he will be chosen. He decides to ask a shooting star to help him, but does his plan work and will he be chosen for his garden's soccer team? Join him on his quest and find out for yourself!
11 June – 12 July• Monday to Friday – 12:00 & 13:00 • Saturday – 12:00 • Sunday – 12:00

For adults

The Sky Tonight

An interesting live lecture on the current night sky is presented every Saturday and Sunday. You will receive a star map and be shown where to find the constellations and planets that are visible this month.
Saturday – 13:00 • Sunday – 13:00
27 April – 13:00

Suitable for teenagers and adults

Bad Astronomy: Myths and Misconceptions

Were the Apollo visits to the moon actually a hoax? Have aliens landed on Earth?
Can you tell your future by the stars? Join the 'Bad Astronomer' as he takes a critical look at popular myths and misconceptions to show audiences how science can be used to evaluate questionable claims.
Until 11 April• Monday to Friday – 14:00
Tuesday evening – 20:00 (& sky talk)
Saturday – 14:30 • Sunday – 14:30

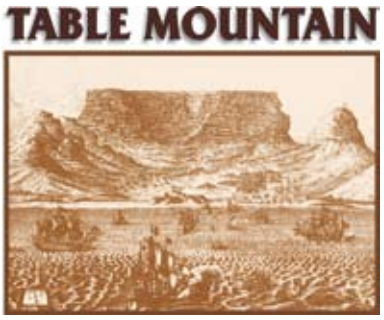

Table Mountain

Table Mountain is more than a famous landmark – it is the only geographical feature on Earth to be represented as a constellation in the sky! Our planetarium presentation explores the remarkable geology and environment of Table Mountain – and the southern skies centred on its celestial counterpart.
12 April – 5 August • Monday to Friday – 14:00 *(excluding 3 May, 7-9 June)* • Tuesday evening – 20:00 (& sky talk) *(excluding 8 June)*
Saturday – 14:30 *(excluding 1 May)* • Sunday – 14:30 • 27 April – 14:00

Planetarium entrance fees

Adults: R20,00; Children: R6,00; Adults (children's show only) R10,00; SA pensioners and students (with cards): R8,00
The Iziko Planetarium is closed for maintenance on the first Monday of the month, excluding school holidays.

Talks, outings and courses

Botanical Society of South Africa, Kogelberg:

Talks: Chelsea Flower Show

David Davies will talk about the Chelsea Flower Show.
18h00 Nivenia Hall HPNGBG (20 March 2010)

Flowers around Napier

Cameron McMaster will talk about flowers around Napier, with special reference to the Renosterveld Conservation Project.
18h00 Nivenia Hall HPNGBG (17 April 2010)

Bushman Art

Dr Renee Rust will talk on Bushman Art of the little Karoo and south of the Langeberg: Content and interpretation.
18h00 Nivenia Hall HPNGBG (15 May 2010)

Millennium seed bank

Karley Cowell will talk on the Millennium Seed Bank.
18h00 Nivenia Hall HPNGBG (19 June 2010)

Botanical Society of South Africa, Pretoria:

Talk: Vegetation management projects

Arnaud le Roux from the Vegetation Management Work Group of the Endangered Wildlife Trust will give a presentation on the vegetation management projects EWT are involved in.
9h30 Education Centre at the Pretoria Botanical Gardens. (19 June 2010)

The Cape Bird Club

Eastern Cape Birding camp

- Karoo National Park
- Mountain Zebra National Park
- Addo Elephant Park
- Wilderness National Park

Contact Hank Hallet (halle@iafrica.com), or 021 685 7465 or 082 825 1788
(27 March to 7 April 2010)

Witwatersrand Bird Club

Easter Weekend Away – Barberton
2-5 April 2010

Back by popular demand, we go birding with John in the 'gem of the Lowveld'. This earlier frontier town is nestled in the Makhonjwa hills and the ravines echo to the sounds of Purple-crested and Knysna Turacos. John will again arrange an exciting programme which will be advised to you on booking. We will be staying at the Digger's Retreat Hotel where camping is also available. *Accommodation:* Rondawels with en-suite bathrooms: R725pp for the weekend (sharing). *Camping:* R275pp for the weekend (shared site). For more details and bookings contact Lauraine in the office on (011) 782-7267 or info@wbc.co.za before Thursday 18 March 2010. Your payment confirms your booking. *Route:* Take the N4 Toll road to Machadodorp. Before Machado tollgate (R46-00), turn right into Machadodorp, then left at the church, drive through town and follow signs (R541) for Badplaas. Drive through scenic area for ± 60 km and at R40 T-junction, turn left towards Barberton. After another 60km, turn left at R40 T-junction towards Nelspruit. *Leader:* John Bunning (083 355 0823). *WBC coordinator:* Murrie Slotar (083 367 6613)

Diarise

- **25-27 June 2010. The 36th G8 summit is to be held in Huntsville, Ontario, Canada.** Consecutively, the 4th G20 summit will be held in Toronto, Ontario, Canada on the same dates. The Group of Seven (G7) was an unofficial forum which brought together the heads of the richest industrialized countries: France, Germany, Italy, Japan, the United Kingdom, the United States and Canada starting in 1976. The G8, meeting for the first time in 1997, was formed with the addition of Russia. The G8 summits during the twenty-first century have inspired widespread debates, protests and demonstrations; and the two- or three-day event becomes more than the sum of its parts, elevating the participants, the issues and the venue as focal points for activist pressure.
- **16 September 2010. The final space shuttle mission, STS-133, is scheduled to launch.** STS-133 (ISS assembly flight ULF5) is the last planned mission of the Space Shuttle Programme. The mission, targeted for launch 16 September 2010, will be to the International Space Station. The mission will transport the Pressurized Multipurpose Module and the fourth ExPRESS Logistics Carrier to the ISS. The mission, which will be the 36th and final US assembly flight to the ISS, will mark the completion of the US Orbital Segment, the 39th and final flight of *Discovery* and the 134th and final flight of the Space Shuttle programme, which began service in 1981.

Prof. Roseanne Diab, Takalani Rambau, Dr Nthabiseng Taole, Prof. Robin Crewe and Dr Xola Mati represent ASSAf in Ghana.

Ghana passes the ASADI VI torch to ASSAf

The Academy of Science of South Africa has been selected to host the 2010 ASADI VI conference, which will be held from 7 to 10 November in Somerset West in the Western Cape.

Following on the ASADI 2009 Conference, which focused on maternal, child and newborn health, in Ghana in November last year, the President of the Ghana Academy of Arts and Science handed the reins to Prof. Robin Crewe, President of ASSAf.

The ASSAf secretariat used the opportunity to showcase its publications, which proved to be in demand. The Ghanaian academy launched a policy-maker booklet developed by ASSAf and Save the Children. The booklet was well received and was graced by video messages from prominent individuals such as Kofi Annan (Former General Secretary of the United Nations), Lord Rees (President of the Royal Society), Ralph Cicerone (President of the US National Academy Sciences), Volker Ter Muelen (President of German Academy of Sciences Leopoldina), Harvey Fineberg (President of US Institute of Medicine) and Mary Robinson (Chair GAVI Alliance and Former President of Ireland).

ASSAf maintained its tradition of involving the chairperson of the Parliamentary Portfolio Committees, and Dr Gogqwana accompanied the ASSAf team. Dr Eddie Mhlanga from the Department of Health also participated in the conference.

The ASADI board praised the ASSAf secretariat for its hard work and evident achievement during the 2008-9 year following a presentation by Prof. Robin Crewe detailing current ASSAf projects.

This ASADI VI conference will concern itself with finding ways of improving access to energy, especially in the sub-Saharan Africa region. Some topics to be covered are traditional versus modern forms of energy; who has access to energy; bridging the gap between rural and urban areas in terms of energy access; affordable and sustainable access to energy; and energy as a universal supply for economic development. These evidence-based solutions will be shared with policy-makers from African governments and the public. A policy-makers' advisory booklet on improving access to energy will be published.

ASADI was launched in 2004 by the US National Academies and aims to strengthen the capability of African science academies to provide evidence-based advice to African government policy-makers and the public. Its vision is to develop African science academies to become credible sources for scientific advice. The conferences provide an opportunity for ASADI representatives to share African academy progress and knowledge gained through policy advisory services to their respective national governments. ASADI also serves to strengthen relations among the African science academies representatives.

Over 150 delegates, consisting of policy-makers, energy experts and African academies representatives are expected to attend. Delegates from the US National Academies, the UK Royal Society and African academies, Dutch and Canadian Academies of Sciences and members of the Network of African Science Academies will be invited to attend the conference.

NASAC and TWOWS move forward in engaging African women in science

The Network of African Science Academies (NASAC) and Third World Organisation for Women in Science (TWOWS) hosted a two-day women for science workshop on 30 November – 1 December 2009 in Nairobi, Kenya.

The workshop was attended by women scientists and representatives from ten African academies. The objectives of the workshop were to inform academy representatives of the recommendations of the InterAcademy Council (IAC) Women for Science study report; learn more about strategic partners in the region; exchange information with academies and other related organisations on progress, challenges and opportunities in promoting women in science; create awareness on employing best practice within academy membership and secretariats; and to discuss models for and agree on follow-up activities for academies in Africa.

The workshop highlighted women's perceptions and experiences, and identified barriers to the advancement of women in science. New principles based on partnerships, gender mainstreaming, networking, recruiting more female scientists in academies and mentorship programmes were discussed. All these are intended to support the present generation of scientists, male and female, who aspire to create a more equitable future.

Workshop participants agreed upon recommendations and priority areas for action by academies. These recommendations form a basis for academies to engage and increase participation of women scientists in academy activities. Men and women scientists are encouraged to work together to implement these recommendations. Workshop participants constituted an *ad hoc* working group for women working in science within the African region.

Representatives at the women for science workshop.

The next step for *SAJS*

The *South African Journal of Science*, which has been fully open access since last year, will be taking its next great step forward in 2010 – moving to an online publishing management platform hosted by AOSIS, OpenJournals Publishing.

This platform provides for online manuscript submissions and tracking, promising faster turnaround times and streamlined processes for ease of use. AOSIS will be partnering with SciELO South Africa to support open access publication in the country.

Open Journals Publishing provides open source publishing systems and support, manuscript management, and is an independent publisher of scholarly journals. The service also hosts and archives the journals online.

This follows another milestone for the journal which last year was one of the first South African journals to be hosted on the fully Open Access platform, SciELO South Africa. SciELO SA benefits researchers and scholars in providing a free-to-publish, free-to-access platform for the best scientific thinking the country has to offer.

SciELO focuses on developing countries where few end-users have access to traditional peer-reviewed academic journals either online or in print form. Access to journals is subscription-based and can be very expensive. Only certain libraries carry them, meaning that there have been severe restrictions in accessibility and affordability up to this point. The Open Access platform for these journals aims to combat these restrictions, while simultaneously enhancing the international visibility of South African research.

Open Access publishing allows research literature comprising academic peer-reviewed journals, conference papers and theses to be placed in an online portal from which they can be downloaded for use. The authors do not have to pay any type of publishing fee. However, it is important to realise that open access by no means equates to 'self-publishing' – all articles conform to the traditional process of journal publishing, entailing critical reading by several peer reviewers who ensure that a rigorous standard of research is upheld. Open Access publishing merely makes these research results available and affordable to a wider audience.

The latest platform, OpenJournals Publishing, entails the re-release of the *SAJS* website, incorporating the new functionality, and with a completely transformed look. After a manuscript is submitted via the online interface of the new website, it follows the editorial route of all peer-reviewed journals, through editors and peer reviewers.

After copy-editing the journal is sent to design for layout. However, where this finished article would only have been published as a finished collection in a specific volume of the journal, the article will immediately be available online as soon as it has gone through the process. As they become available online, the articles will be collated and await print in the next hard copy edition of the *SAJS*. This eliminates any delays between the article as a finished product and its being accessible to interested readers.

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Wake up – you could do with a nap!

New studies from the University of California, Berkeley, shows that an hour's nap during the day can dramatically boost and restore your brain power – so not only does it refresh you, it also means you wake up a bit smarter than before you took your nap.

What's more, the longer you stay awake, the more sluggish your mind becomes – it slows down. Therefore, when it comes to cramming for exams, it's probably not a good idea to stay up all night. The researchers found that doing so actually makes it harder to cram in new facts – by a massive 40% – because some parts of your brain shut down through sheer fatigue, thanks to being deprived of sleep.

In the recent UC Berkeley sleep study, 39 healthy young adults were divided into two groups – nap and no-nap. At noon, both groups were subjected to a rigorous learning task intended to tax the hippocampus, a region of the brain that helps store fact-based memories, and the results showed that both groups performed comparably.

At 2 pm, the nap group took a 90-minute nap while the no-nap group stayed awake. Then, at 6 pm, both groups again went through the another round of learning exercises – those who had enjoyed a nap during the day did much better than those who had to stay awake; in fact, the 'nappers' were able to learn better than they had previously.

It's almost like your email inbox – once it's full, you need to clear it before you can receive new messages. So the message is clear – a midday can be good for you. Source: EurekAlert

Cars go electric

Electric cars are quieter than petrol or diesel-powered vehicles, they need less maintenance, and they are eco-friendly. So it's no surprise that authorities in the Harz region of Germany plan to set up a network of smartly located charging stations covering the entire Harz region and so make electric cars a regional feature.

The success of electric cars will stand or fall with the power supply – and that means a series of charging stations placed right where the cars can charge up – so that they will be able to reach a city 60 km away without any problem. An on-board computer will act rather like the fuel gauge we all know so well, but this will do somewhat more… The vehicle's so-called mobility control centre will monitor the vehicle's battery charge, the traffic situation and other data and then, using satellite navigation, advise a driver to head for a recommended charging station based on the battery's charge level. The control centre will even tell a driver which charging stations are occupied, being serviced, are closed or even those offering the best prices for a recharge.

The official test phase for the new system will begin at the end of 2010 and 25 electric cars are intended to be on the road in the Harz region by June 2011. Source: Fraunhofer-Gesellschaft

Electric cars like this one above will be rolling through the Harz region in the future. The fleet of cars is supposed to be increased to twenty-five vehicles by June 2011. Image: Fraunhofer IFF/Dirk Mahler

NASA takes a WISE view of the universe

The first survey images from NASA's Wide-field Infrared Survey Explorer, or WISE were released recently, and the space telescope has already beamed back more than 250 000 raw, infrared images. Four new, processed pictures illustrate a sampling of the mission's targets – a wispy comet, a bursting star-forming cloud, the grand Andromeda galaxy and a faraway cluster of hundreds of galaxies. The images are online at http://www.nasa.gov/mission_pages/WISE/multimedia/images20100216.html.

Apart from superb images of our beautiful universe, WISE is also helping to track asteroids, comets and other stellar objects – a vital role should any of these objects approach Earth.

One image shows the beauty of a comet called Siding Spring. As the comet streaks towards the sun it sheds dust forming a tail about 16 million kilometres long that looks like a streak of red paint that glows in infrared light visible to WISE.

WISE will photograph a huge number of objects – including galaxies, such as Andromeda, which is a bit bigger than our Milky Way and about 2.5 million light-years away.

The space telescope sees dusty comets and rocky asteroids tracing the formation and evolution of our solar system, and using it, scientists can map thousands of forming and dying solar systems across our entire galaxy, and even other galaxies. Other mission targets include comets, asteroids and cool stars called brown dwarfs.

Comet Siding Spring appears to streak across the sky like a superhero in this new infrared image from NASA's Wide-field Infrared Survey Explorer, or WISE Its tail is about 16 million kilometres long. Image: NASA/JPL-Caltech/UCLA

The immense Andromeda galaxy, also known as Messier 31 or simply M31, is captured in full in this new image from NASA's Wide-field Infrared Survey Explorer, or WISE. Image: NASA/JPL-Caltech/UCLA

MIND-BOGGLING MATHS PUZZLE FOR *QUEST* READERS

QUEST Maths Puzzle no. 13

5	2	5	4	1
7	6	1	7	3
5	9	4	1	5
2	3	8	3	2
3	1	4	9	6

Win a prize!

Send us your answer (fax, e-mail or snail-mail) together with your name and contact details by 15:00 on Friday, 28 May 2010. The first correct entry that we open will be the lucky winner. We'll send you a cool Truly Scientific calculator! Mark your answer 'Quest Maths Puzzle no. 13' and send it to: Quest Maths Puzzle, Living Maths, P.O. Box 478, Green Point 8051. Fax: 0866 710 953.
E-mail: livmath@iafrica.com. For more on Living Maths, phone (083) 308 3883 and visit **www.livingmaths.com**.

Solution to *QUEST* Maths Puzzle no. 12

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There were two winners for this puzzle: Richard Becker and Mrs. I Govender, both from the Kings School, Linbro Park