SCIENCE FOR SOUTH AFRICA

Quest

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Swartkrans Cave:
Unlocking the secrets of our past

Roots, Bugs And Venison: Prehistoric cuisine

Uncovering early human behaviour

Were our early ancestors murderers and head-hunters?

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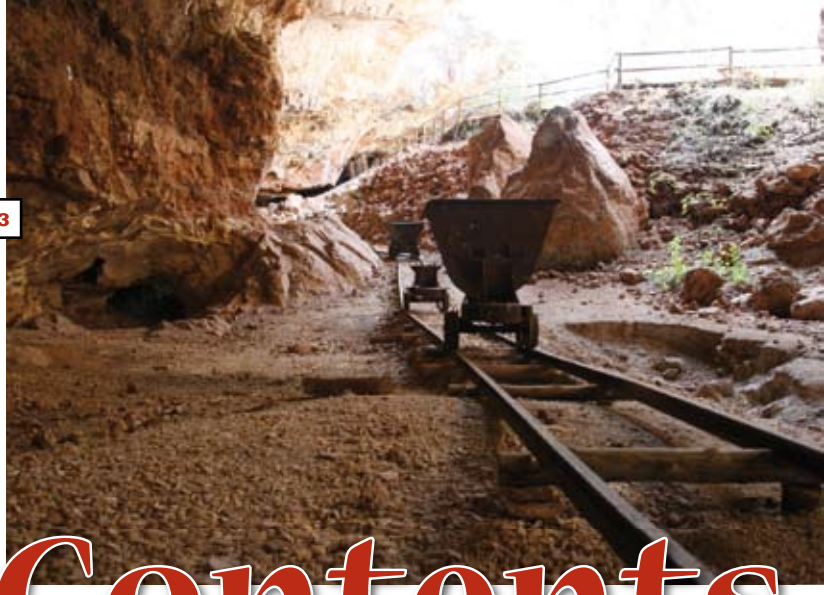

Contents

VOLUME 5 • NUMBER 2 • 2009

Cover stories

Features

Regulars

Work in progress.

Images: Jason Heaton and Bridget Farham

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Humankind arising

'Nothing in biology makes sense except in the light of evolution.' This was said in 1973 by one of the greatest of all geneticists and evolutionary biologists, the late Theodosius Dobzhansky. He went on to say that the concept of evolution has 'provided new and in some ways revolutionary answers to questions men have been asking for centuries. The two most important of these are: 'Why am I here, what is the purpose of human existence?', and 'What is the nature of the world of life that surrounds us?'.

Our understanding of evolution tells us that we are here because of a long series of past events that are no different from the events and processes that produced the myriad of different organisms that surround us. The most important processes are: interactions between highly diverse organisms and their environment, the continuity of heredity and cultural tradition and the occasional disturbance of these regularities by chance.

It is this fact of evolution that this edition of *Quest* looks at in some detail – and specifically the detail of human evolution that has been uncovered right on our own doorstep – in the rich fossil sites of the Cradle of Humankind. It is here and in East Africa that humankind's evolutionary development through to modern-day *Homo sapiens* has been painstakingly uncovered by great scientists such as Raymond Dart, Robert Broom, John Robinson and Phillip Tobias. These names are embedded in the history of evolutionary biology – as are, and will remain, those of some of the contributors to *Quest* – CK (Bob) Brain, Travis Pickering, Jason Heaton, Morris Sutton and Nik van der Merwe.

Swartkrans Cave contains one of the greatest concentrations of hominin fossils ever found – and it is at this site that we have started to uncover some of the most important secrets of our ape-men ancestors, such as how they ate and how this contributed to the development of the brain that led to modern humans. The whole area around Swartkrans, which overlooks the Sterkfontein site, is redolent of our past. On a recent visit to the site, it was easy to imagine early hominins living and foraging in the area, even though the fauna and flora have changed somewhat.

Dobzhansky says, 'If man has arrived at his present state as a result of natural processes rather than by a supernatural will, he can learn to control these processes. … The limitations we must overcome are chiefly our own difficulty in understanding the vast complexity of the world that surrounds us, as well as the weight of tradition, the conservatism of cultural heredity and the egotism of individuals that restricts our ability to act on the basis of principles that underlie natural processes.' The careful, painstaking work being carried out by members of the Swartkrans Palaeoanthropological Research Project will ensure that we will eventually have a finer understanding of the science around our origins.Without this, we cannot easily shape our future.

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

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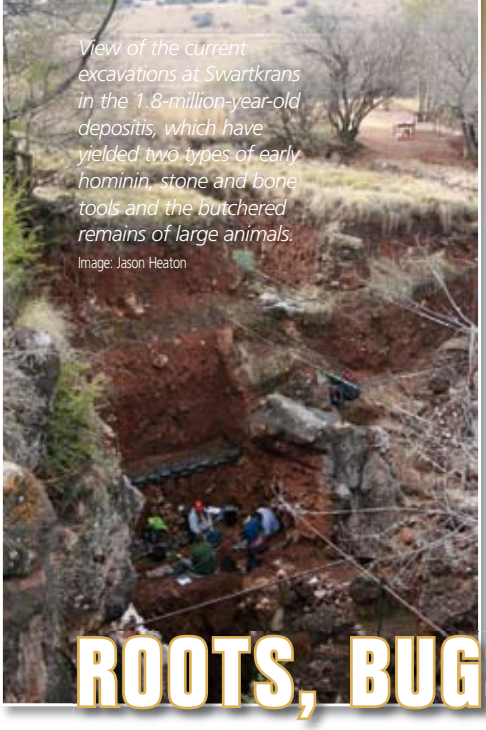
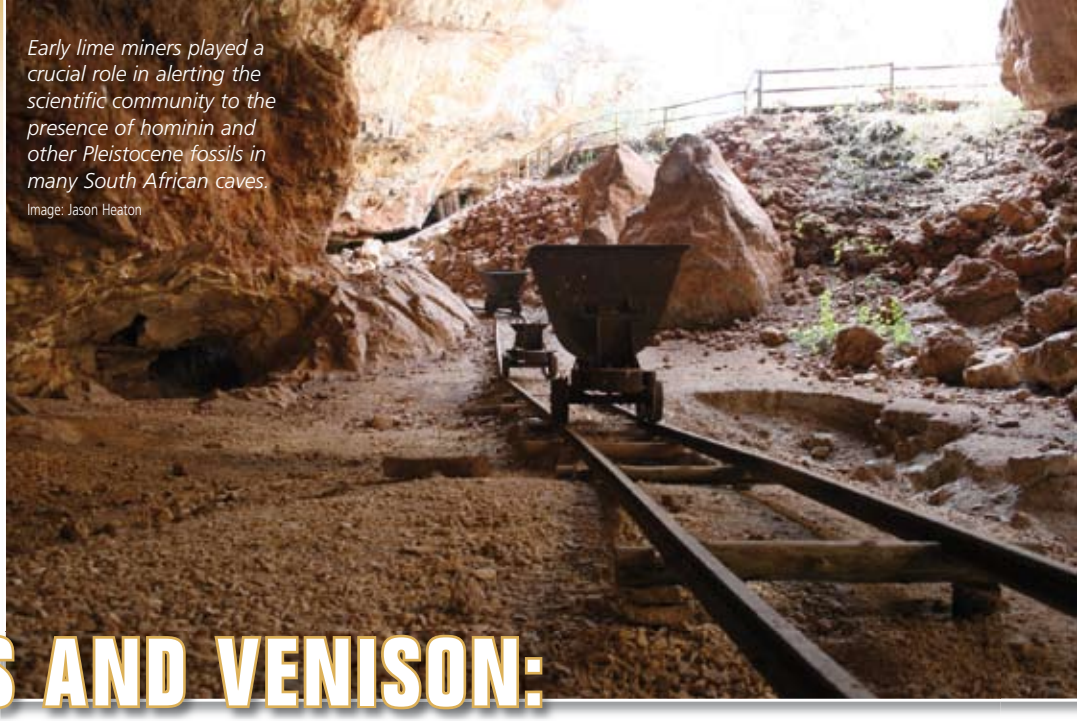


View of the current excavations at Swartkrans in the 1.8-million-year-old depositis, which have yielded two types of early hominin, stone and bone tools and the butchered remains of large animals.
Image: Jason Heaton



Early lime miners played a crucial role in alerting the scientific community to the presence of hominin and other Pleistocene fossils in many South African caves.
Image: Jason Heaton

ROOTS, BUGS AND VENISON: Prehistoric cuisine at Swartkrans Cave

Travis Pickering and **Jason Heaton** show us how the fossil record has led us towards an understanding of human evolution.

Mines and anthropology

The study of human evolution in South Africa owes a great debt to an unlikely source. Long-maligned in textbooks and secondary academic sources as destroying fossils, it was early 20th century lime miners who first exposed and alerted scientists to the rich treasure troves of human prehistory encased in caves like Taung, Sterkfontein, Kromdraai and Swartkrans. Gold and lime mining were intimately linked in those pioneer days, because lime is a catalyst in the Macarthur-Forrest cyanide process used for extracting gold from low-quality ore.

In order to recover lime from the underground caves in which it was contained, miners also had to remove, by hammering, digging and dynamiting, calicified cave sediments (breccia) that were found along with the lime. In the process, the miners also discovered that the sediments contained fossilised bones.

The Macarthur-Forrest process

This is a process of gold cyanidation and is a metallurgical technique for extracting gold from low-grade ore by converting the gold to water-soluble aurocyanide metallic complex ions. It is the most commonly used process for extracting gold from ore, but is highly controversial because cyanide is so poisonous.

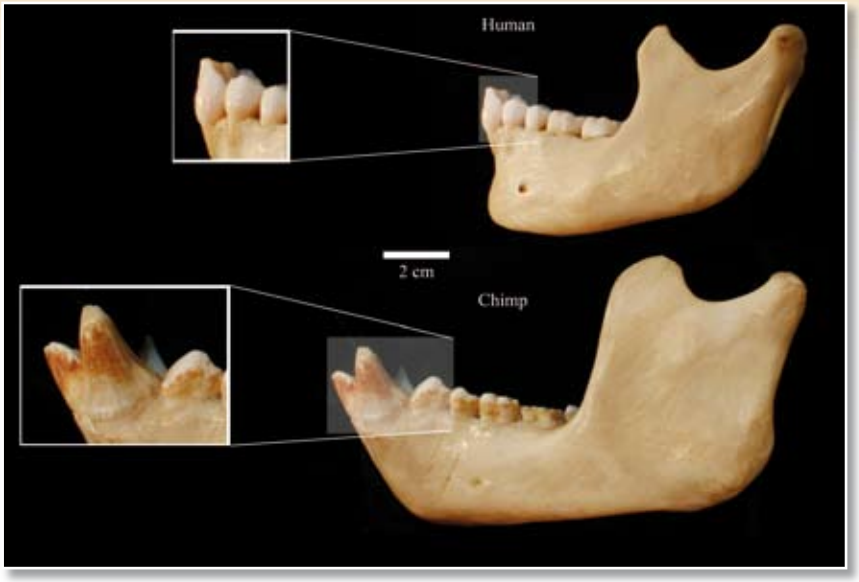
Early hominins

An accompanying article in this issue, by Bob Brain, tells the story of Raymond Dart's fortuitous receipt of a block of such fossil-bearing sediment, which contained the skull of the Taung Child. After careful study, Dart determined that the skull represented an extinct species of human he called *Australopithecus africanus* – the southern ape of Africa. Although the Taung Child's skull was in many ways ape-like, with a small braincase and large jaws and teeth, a key human trait was obvious in the base of its cranium. The hole through which the spinal cord travels to connect with the brain, the foramen magnum, is situated toward the front of the child's skull. This morphology is typical of an obligate biped (like a human and unlike an ape) whose head rests on top of an upright spine.

In comparison to modern humans, it is natural to think of *Australopithecus africanus*, which we now know dates between 3 – 2 million years old, as primitive. But, research since Dart's day has revealed a myriad of species that are ancestral to humans and predate *Australopithecus africanus* by millions of years. Biomolecular evidence indicates that the taxonomic group to which modern humans belong – the hominins – diverged from the chimpanzee lineage somewhere in Africa about 8 – 5 million years ago. And, recent palaeontological research ▷▷

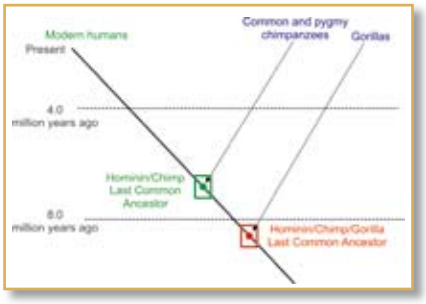
Top: Piles of fossil-bearing cave sediments from Swartkrans. These calcified sediments are called breccias and require hammers and chisels to remove them from the cave and then subsequent processing in acetic acid to remove fossils without inflicting damage on them.
Image: Jason Heaton

Above: View of the bases of a modern human (left) and modern chimpanzee cranium, showing the relative positions of the foramen magnum in an obligate biped (the human) and a quadrupedal ape. Image: Jason Heaton



Top: An Ardipithecus *fossil jaw from the Gona region of Ethiopia.* Image: Sileshi Semaw

Above: A cast of the remains of Lucy. Image: Wikimedia commons



Above: Side views of human and chimpanzee jaws, illustrating a fundamental anatomical difference between hominin and non-hominin primates. Living and extinct hominins lack(ed) an upper canine honing complex in their lower jaws, while apes possess this feature. Image: Jason Heaton

Left: Hypothesised relationships of modern humans and African apes and their extinct ancestors, based on genetic and palaeontological data.

across the continent is augmenting the fossil record of this time span.

Currently, there are three possible candidates for the oldest known hominin species. One of these, *Ardipithecus kadabba*, was discovered by palaeoanthropologist Yohannes Haile-Selassie and his colleagues in geological deposits that occur in the Middle Awash River Valley of Ethiopia, and are dated between 5.8 – 5.2 million years old. Ten years earlier, in 1994, a research group led by Tim White announced the first known species of *Ardipithecus*, *Ardipithecus ramidus*, which was found in the same region as *Ardipithecus kadabba*, but in a geological context about one million years younger.

White, Haile-Selassie and their coworkers argue that *Ardipithecus kadabba* and *Ardipithecus ramidus* are time-successive (that is, chrono-) species that represent the earliest appearance of the hominin lineage. The genus *Ardipithecus* is more closely allied to modern apes in much of its cranial and dental anatomy than it is to later-occurring hominin species. Like modern chimpanzees and unlike hominins, *Ardipithecus* fossils possess large canine teeth and relatively small molars capped with thin enamel.

While little is published about the skeleton of *Ardipithecus* below the cranium, the few arm bones that have been described display a mix of human-like and ape-like features.

Human or ape?

With so many morphological similarities to apes, it is reasonable to wonder why *Ardipithecus* is considered a human ancestor rather than an ape ancestor. Supporters of the hominin status of *Ardipithecus* point to two important anatomical features that it shares with later hominins. First, the position of the foramen magnum is towards the front of skull in the *Ardipithecus*, as it is in *Australopithecus africanus* and in modern humans. The second feature that purportedly links *Ardipithecus* more closely to living humans than to living apes is subtle, but just as critical as the position of the foramen magnum. Although *Ardipithecus* canine teeth are large, they are also blunt and less projecting and dagger-like than those of apes. In addition, apes have what are called sectorial lower third premolars, the front faces of which slope backward so that the upper canine locks between it and the lower lateral incisor when the upper and lower teeth are in contact.

Thus, the back edge of the upper canine glides across this slope as an ape opens and shuts its mouth, honing that canine edge. In contrast, no hominin, living or extinct, possesses this canine honing system. Although the upper canine and lower third premolar of *Ardipithecus kadabba* interlocked, the system was not so developed as to sharpen the top fang as thoroughly and consistently as seen in apes.

Top left: Comparison of the lower jaws and teeth of a modern human and Australopithecus robustus *from Swartkrans. Note the extreme robusticity of the latter's mandible and its enormous premolars and molars, a condition called megadontia and one that, in part, defines the genus* Australopithecus. Image: Jason Heaton

Top right: Australopithecus afarensis *reconstruction. Displayed at Museum of Man, San Diego, California.* Image: Wikimedia commons

Above: Cranium SK 48 from Swartkrans, a representative of Australopithecus robustus*, one of three species of robust australopithecine and the only one known from South Africa.* Australopithecus aethiopicus *and* Australopithecus boisei *are the two known species of robust australopithecine from East Africa.* Image: Jason Heaton

A challenge to the hominin status of *Ardipithecus* has been offered by a Kenyan and French team of palaeoanthropologists working in 6.0 million-year-old deposits in the Tugen Hills of Kenya. Team leaders Brigitte Senut and Martin Pickford stress the apelike features of *Ardipithecus* and relegate it to a position as an ape ancestor, while offering their own recent discovery, *Orrorin tugenensis*, as the ancestor of all species leading to modern humans. *Orrorin* is represented by various teeth, mandible fragments and pieces of arm and leg bones, and like *Ardipithecus*, retains many primitive aspects in its anatomy. The same can be said for the remarkable 7.0-million-year-old cranium recently recovered by palaeontologist Michel Brunet and his team in the Djurab Desert of northern Chad.

Critics of the hominin status of this cranium, assigned to the novel taxon *Sahelanthropus tchadensis*, claim that it is actually just an ape, with no indication of obligate bipedal locomotion, crucial to a species' inclusion in the hominin lineage. Other researchers, such as White and Haile-Selassie, see enough anatomical continuity between *Sahelanthropus*, *Orrorin* and *Ardipthicus* to suggest that all three should be included in the same genus which, if correct, would push the earliest known appearance of *Ardipithecus* one million years deeper into prehistory. Thus, there is still no clear picture of this earliest phase of the human story and as the dust settles around these new and exciting discoveries, many experts are taking a wait-and-see stance before naming the definitive human ancestor.

The origins of humankind

Regardless, it was not until long after the extinction of *Ardipithecus*, *Orrorin* and *Sahelanthropus*, some time around 2.3 million years ago, that the first species of our own genus, *Homo*, appeared, as indicated by fossil evidence from the fossil locality of Hadar, in north-eastern Ethiopia. In the time span between the demise of *Ardipithecus*, *Orrorin* and *Sahelanthropus* and the rise of early *Homo*, hominins were represented on earth by the so-called ape-men or australopithecines, members of the genus *Australopithecus*. Dart's Taung Child, *Australopithecus africanus*, was only one of several species included in this widely distributed and long-lived group of hominins. For instance, the most famous australopithecine skeleton, Lucy, belonged to a geologically older species called *Australopithecus afarensis*, known from 3.6 – 3.0-million-year-old sites in Ethiopia, Kenya and Tanzania. And *Australopithecus afarensis* was preceded in East Africa by *Australopithecus anamensis* (4.2 – 3.9 million years old).

The adaptation that most specifically sets the genus *Australopithecus* apart from the provisional hominins of earlier times and the modern apes is called megadontia. Megadontia refers to enlargement of the premolars and molars, the cheekteeth.

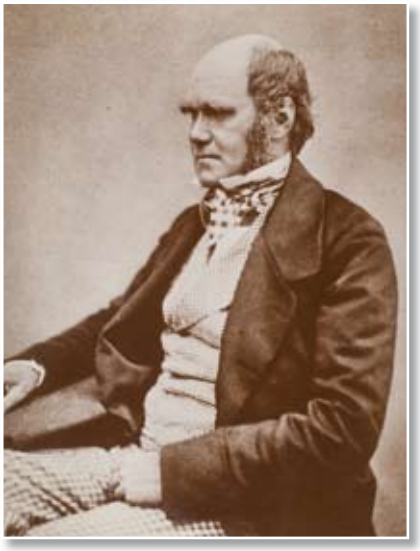
But, not only did the cheekteeth of *Australopithecus* increase in absolute size through time, from species to species, but they also increased in size relative to body size. They also changed shape in some species, with the premolars becoming molar-like in their anatomy. In addition, the cheektooth enamel of *Australopithecus* is much thicker than that possessed by the earliest putative hominins and the apes. Collectively, these features functioned as part of an adaptive complex that involved increasingly more powerful chewing capabilities as the australopithecines evolved.

The apex of this unique morphology occurs in a group of ape-men referred to as robust australopithecines.

The particulars of skull morphology that link the robust australopithecines together as a distinct sub-group of *Australopithecus* are anatomical consequences of their extreme tooth size and their need for hyper-chewing power. For example, a high ridge of bone – the sagittal crest – that runs down the midline of the male robust australopithecine cranium functioned to anchor immense chewing muscles originating on the mandible. The mandible itself is massively deep and the cheekbones are placed far forward on the face of robust ape-men so that this huge jaw musculature could be further accommodated on the sides of the head.▹▹

Above left: Swartkrans is remarkable for its large collection of Australopithecus robustus *fossils, which derive from over 100 individual ape-men.* Image: Jason Heaton

Above right: Swartkrans was the first site in the world to yield evidence of two contemporaneous types of early hominin, Australopithecus robustus *and* Homo erectus*) (represented by this beautifully preserved cranium SK 847). Subsequently, the co-existence of robust ape-men and early* Homo *has also been confirmed in East African palaeoanthropoligical contexts.* Image: Jason Heaton



Top: Charles Darwin (1809 – 1882). Image: Wikimedia commons

Above: The late South African palaeoanthropologist John Robinson proposed the influential 'dietary hypothesis', which argued that robust ape-men were specialised herbivores. Image: University of the Witwatersrand

Herbivory and carnivory

The earliest known robust ape-man species, *Australopithecus aethiopicus*, appears in the fossil record of East Africa around 2.7 million years ago. That emergence is at roughly the same time as the first appearance of stone tools in the archaeological record (2.6 million years ago) and makes *Australopithecus aethiopicus* a near contemporary of *Australopithecus garhi* (2.5 million years ago), the species that might have given rise to the genus *Homo* soon after. The coincidence of these three events – the rise of the robust australopithecines, the rise of early humans (*Australopithecus garhi*) and the invention of stone tools – is exciting and complicating for palaeoanthropologists. But, that was not always the case.

Conventional wisdom has long held that Africa experienced an extreme change to more open, savannah habitats between 3.0 and 2.5 million years ago and that this change caused the split of the hominin lineage into the robust ape-men and early *Homo*. The idea that adaptation to savannahs drove human evolution is even older than the discovery of hominin fossils from Africa. As early as the 1870s, Charles Darwin argued that open habitats were the crucible of human evolution – the idea being that forest fruits favoured as food by our ape ancestors would no longer be available to proto-hominins among the grassland flora.

As the fossil record filled in throughout the 20th century and scientists began to gain a more sophisticated understanding of the ancient African environment, the 'savannah hypothesis' became increasingly developed – and Swartkrans Cave, in particular, played and continues to play a crucial role in that development.

By the late 1950s, South African palaeoanthropologist John Robinson proposed a refinement of the 'savannah hypothesis' called the 'dietary hypothesis'.

At that time, many researchers assumed that Dart's *Australopithecus africanus* was directly ancestral to the genus *Homo* and that it was also of the same period as a robust ape-man from South Africa, now called *Australopithecus robustus*.

Swartkrans has yielded the largest number of *Australopithecus robustus* fossils in the world, as well as several of an early form of *Homo*, *Homo erectus*, and was the site upon which many of Robinson's ideas were developed.

Robinson argued that *Australopithecus robustus* adapted to the savannah by maintaining an herbivorous diet, but that it diverged from its forest ancestors because it specialised on the coarse vegetable matter available in open country. These kinds of resources, such as nuts and plant roots, are notoriously tough to chew and it was in this light that the large jaws and teeth of the

Above: African bovids can be grouped as browsers versus grazers. The type of vegetation they consume – browse or graze – will be differentially expressed in their $^{12}C/^{13}C$ ratios. Image: Jason Heaton

Above right: The $^{12}C/^{13}C$ ratio of a carnivore will reflect that of its prey – crucial information in a palaeontological context that can assist in reconstructing the diet of extinct animals. Image: Jason Heaton

Right: Hyenas are carnivores; ape-men were long presumed to be mostly herbivorous. Thus, it was surprising when Australopithecus africanus *fossils yielded $^{12}C/^{13}C$ ratios similar to those of hyenas.* Image: Jason Heaton

Gracile, in this context, refers to hominin forms with more lightly built skulls, lacking the large teeth and jaws of the robust species.

robust australopithecines made adaptive sense. In contrast, the teeth and jaws of the presumptive *Homo* ancestor *Australopithecus africanus* are more gracile, and Robinson contended that that species (and later, *Homo*) solved the problem of savannah survival by increasingly incorporating meat into its diet.

Meat, readily available on the African savannah, is soft and does not require its consumer to have a massive dental battery to break it down. Muscle does, however, adhere to bones and comes in large packages, so a cutting technology would be most useful for a blunt-toothed hominin that began to exploit this resource. Thus, the invention of stone tools becomes completely explicable and assignable to proto-*Homo* with the resource partitioning envisaged in Robinson's dietary hypothesis. Further, acquiring meat requires a smarter brain than does picking nuts or grubbing for roots. It was not surprising therefore that our large-brained, small-faced lineage persists and the small-brained, large-faced robust ape-men eventually went extinct.

Opportunistic feeders

Of course, the model was too simple to ever hold up. Three avenues of recent investigation argue against an exclusive specialised nut or root diet for the robust australopithecines. First, nutritional analyses of those rather low-quality savannah plant foods suggest that it would be exceedingly difficult, if not impossible, for a large-bodied primate like *Australopithecus robustus* to meet its daily caloric and protein requirements by relying on them. Second, studies of damage (scratches and pits) on the chewing surfaces of robust australopithecine teeth, when compared to the damage seen on modern primate teeth of known dietary specialisation, demonstrate that they ate a variety of food types. Third, isotopic analyses of robust australopithecine teeth indicate that the group was comprised of diverse feeders.

Isotope research on fossil hominins requires some explanation. All plants take up two types of stable carbon (C) isotopes, ^{12}C and ^{13}C, during photosynthesis. However, tropical grasses and sedges can convert ^{13}C into sugars and other tissues more easily than can tropical trees and shrubs. As a result trees and shrubs tend to 'select against' ^{13}C during photosynthesis, and thus have lower levels of this isotope than do tropical grasses and sedges. Thus, trees and shrubs form a distinct group as opposed to grasses and sedges when analysing their proportions of ^{12}C to ^{13}C.

Animals that eat these plants contain the same proportion of ^{12}C to ^{13}C as the type of plant group they consume – trees and shrubs versus grasses and sedges.

Likewise, meat-eating animals reflect the $^{12}C/^{13}C$ ratios of the herbivore prey that they consume.

In a groundbreaking 1999 study, palaeoanthropologists Matt Sponheimer and Julia Lee-Thorp demonstrated that *Australopithecus africanus* teeth from the South African site of Makapansgat have $^{12}C/^{13}C$ ratios similar to those of meat-eating hyena teeth also recovered there.

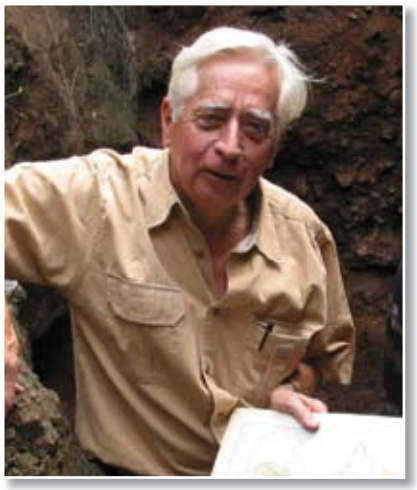
This suggested to the researchers that *Australopithecus africanus* was sometimes carnivorous, feeding at least occasionally on the carcasses of grass-eating ungulates.

(See *Carbon isotopes, photosynthesis and archeology* in this issue for more details on this line of research.)

Digging for termites?

However, critics argued that the $^{12}C/^{13}C$ ratio in *Australopithecus africanus* can be explained by other factors, such as its consumption of grass-eating insects or water-loving sedges. When a similar $^{12}C/^{13}C$ ratio was identified in *Australopithecus robustus*, the supposed specialised nut- or root-feeding vegetarian, understanding the non-ungulate sources of the grass signal became even more crucial. Researchers, working within the frame of Robinson's dietary hypothesis, originally classified artefacts that were made from antelope bones and that were found prominently at Swartkrans (and later at other *Australopithecus robustus* sites like Sterkfontein and Drimolen) as root-digging tools. ▹▹

Left: Early Stone Age technology was simple but effective. Sharp flakes were used to cut meat from bones and large cobbles were used to crack open antelope leg bones for access to nutrient-rich marrow. Image: Jason Heaton



Below left: CK (Bob) Brain, legendary South African natural historian and palaeontologist. Brain's long-standing excavations at Swartkrans revealed many remarkable aspects of early hominin adaptation and behaviour including the idea that Australopithecus robustus *created and used bone tools to harvest edible roots.*

Specifically, Bob Brain's inspired skills of observation and lateral thinking led to the important scientific epiphany that the wear patterns on the fossil bone tools and the digging damage incurred on screwdrivers he used to excavate Swartkrans were nearly identical.

Brain further reasoned (very sensibly!) that *Australopithecus robustus* wasn't digging at Swartkrans over a million years ago for fossils, but must have instead been interested in some subterranean resource important for its survival. This led him to experiment with modern bones that he used to dig for common edible resources still growing on Swartkrans Hill today, the underground bulbs of lilies and grass stars. That damage, too, matched the fossil bone wear and thus the hypothesis of a bone tool root-digging adaptation for *Australopithecus robustus* was well accepted.

The new isotope results on ape-man fossils that give a grass-eating signal, in part, prompted other researchers to explore the idea that there may have been an alternative underground food that *Australopithecus robustus* was instead targeting with its digging activities. In particular, it was argued, based on a new round of experimental work, that the bone tools were rather used by *Australopithecus robustus* to open the mounds of grass-eating termites.

However, more testing and logical scrutiny is required before the root-digging scenario is invalidated and can be abandoned in favour of the termite-foraging hypothesis. For instance, root extraction *necessarily* requires digging and digging with tools if you were a prehistoric hominin lacking claws. A termite mound, in contrast, can be breached or even toppled simply by kicking or hurling a rock at it. It needs to be demonstrated that termite harvesting is somehow more efficient by digging holes than by causing swarms by other means of penetrating it. Additionally, Matt Sponheimer analysed termite isotopes and concluded it was unlikely that termites alone could explain the high C_4 signal in *Australopithecus robustus*. Sponheimer's data show a 3 – 40% C_4 component in ape-man diets; if that was gained entirely from termite consumption, it would indicate a diet of nearly 100 % termites – a very unlikely situation.

Was *Homo* the only early carnivore?

The termite-foraging hypothesis has, though, gained a real foothold in the secondary literature of palaeoanthropology. This probably has more to do with our perceptions of what *Australopithecus should have* been doing, rather than what it *was* doing. For many, eating the flesh and marrow of large vertebrates cannot be attributed to the ape-men; hominin meat-eating has to stay the exclusive capacity of the *Homo* lineage (probably including *Australopithecus garhi*). Carnivory is, after all, one of the primary factors that made us human – supplying the high energy and quality nutrients to grow big, smart brains, ensuring the survival and eventual primacy of our species. *Australopithecus* was a small-brained idiot that went extinct.

However, another school of opinion has emerged that is willing to consider the isotopic data in a more straighforward way. If those data are saying that the robust ape-men could have consumed large vertebrate flesh, then maybe they did. How, then, could one explain the extraordinary jaws and teeth of those hominins? Wild animals experience fat and lean times throughout a year. Good times of year provide an abundance of the animal's preferred foods. Harsher periods challenge the animal to subsist on other, non-preferred resources – called fallback foods.

Among modern apes, gorillas and chimpanzees both prefer fruit, but each can also subsist on lower-quality leaves and piths as fallback foods when seasons change and fruit becomes scarce. The difference between these two species, though, is that gorillas are able to subsist *entirely* on fallback foods, while chimpanzees cannot: they still require some fruit to survive.

Researchers Greg Laden and Richard Wrangham have suggested the extreme morphology of the robust australopithecine skull and teeth might be an indication that these hominins followed a gorilla-like strategy of relying completely on fallback foods when preferred foods like fruit and meat were in short supply. On the ancient African savannah such fallback foods probably included roots and perhaps nuts. Adaptations for exploiting these types of resources are the ones that should be prominently expressed in the anatomy of an animal that takes a gorilla-like approach. This is because efficient exploitation of a single (or small range of) non-preferred resource(s) is *essential* for an individual's survival during that time period. Species that adopt a more chimpanzee-like strategy – only using fallback foods to *supplement* the diet in a season when preferred foods become rare – are released from the pressure to specialise morphologically. Hence, the *Homo* lineage, the presumed chimpanzee-like hominin group, shows fewer extreme specialisations in its craniodental anatomy than seen in the robust australopithecines.

The place of stone tools

We must, of course, also consider the role of emergent stone technology in such a scenario and its potential to further release *Homo* from evolutionary pressures that were outside its body structure. There is a complication, though: robust australopithecines are found in archaeological association with stone tools almost as frequently as is

Above: Numerous bone tools, similar to the modern experimentally produced one illustrated here, have been recovered from Swartkrans and other robust ape-men cave sites in South Africa. It is hypothesised alternatively that they were used by australopithecines to dig up edible roots (left) or termites (right). Image: Jason Heaton

early *Homo*. Further, the isotopic data discussed above implicates ape-men in meat-eating to some degree, and much experimental and archaeological work, as well as simple logic, indicates that stone tools were probably invented to process animal carcasses.

No hominin that ever existed possessed the imposing strength and speed, tearing claws, and flesh-slicing and bone-crushing dentitions of the lions, leopards, hyenas and host of extinct predators with whom they competed for animal carcasses in the distant past. Those facts, while disadvantages for hominins millions of years ago, are happy coincidences for the scientists who attempt to reconstruct their foraging behaviours. In place of claws and teeth, early hominins used stone tools to process carcasses and those tools left incidental traces on the butchered bones. It is through analysis of those traces that palaeoanthropologists have begun to build a picture of hominin meat-eating.

The two major categories of butchery damage imparted on bones by hominin tools are cutmarks, made by the sharp edge of a cutting tool when it accidentally sliced through overlying meat into underlying bone, and percussion marks, created when hominins used river cobbles to pummel open and harvest the marrow of animal leg bones. Cutmarks and percussion marks are seen alongside the stone tools that produced them, starting in the earliest recognised archaeological record from East Africa at 2.6 million years ago. This is not surprising because those first stone artifacts come in two basic forms – sharp cutting flakes and heavy cobble hammers – both of which are ideal for butchery and less perfect for other activities.

As with the earlier East African occurrences, this trace evidence of butchery on animal bones is a common component of the Swartkrans archaeological record between 1.8 – 1.0 million years ago. It documents a very successful strategy of animal food exploitation, in which hominins appear to have enjoyed primary access to preferred, heavily meat-laden parts of carcasses before those portions could be consumed by the host of carnivorous competitors that shared the Swartkrans landscape. Conventional wisdom, following from Robinson's 'dietary hypothesis', touted these as exclusive abilities of *Homo erectus*, a more 'human-like' early hominin than was *Australopithecus robustus* and the other ape-man species. But, as reviewed here, a truly unbiased reading of the available evidence shows that this conclusion rests on a shaky scientific foundation.

Changing perceptions and paradigm shifts are indications of a healthy and dynamic academic discipline, and Swartkrans Cave and its remarkable record of prehistoric life continues to catalyse palaeoanthropology in both ways. The stark dietary – and thus, by extension, lifestyle – separation for the robust ape-men and early *Homo* modelled by Robinson's 'dietary hypothesis' now seems unlikely. With two contemporaneous species of large-brained, omnivorous hominins sharing the Swartkrans environs 1.8 – 1.0 million years ago, the challenges of differentiating their behavioral and cultural uniqueness will remain a daunting but exciting challenge for students of human evolution. □

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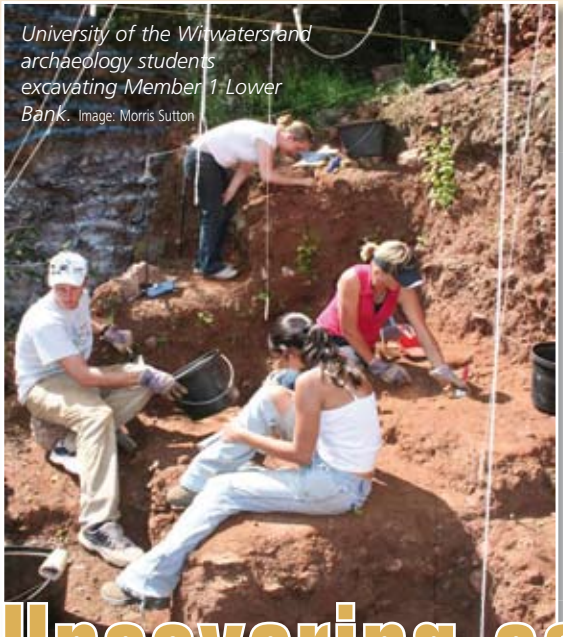


University of the Witwatersrand archaeology students excavating Member 1-Lower Bank. Image: Morris Sutton

A view of the modern Sterkfontein site from Swartkrans. Image: Bridget Farham

Uncovering early human behaviour

Stone and bone artefacts from the Early and Middle Stone Age provide a window into early human behaviour. **Morris Sutton** explains the contribution of the excavations at the Swartkrans fossil site.

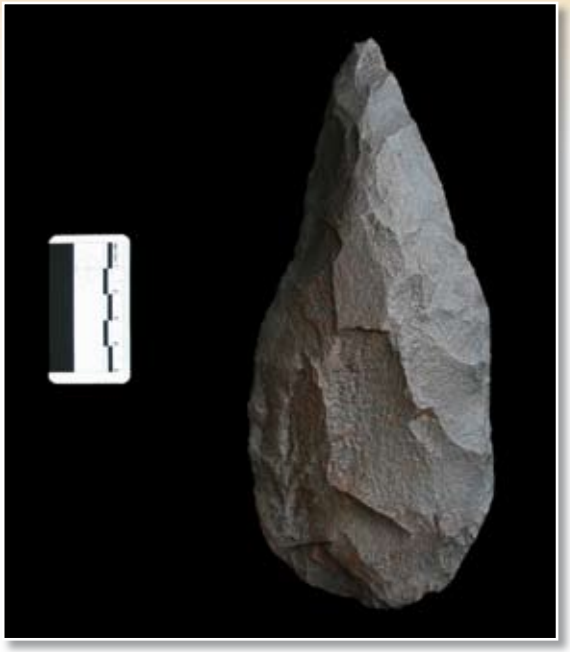
The contribution the Cradle of Humankind sites have made to the world's hominin fossil record is immense. Since the 1930s when Robert Broom began recovering fossils at Sterkfontein, the wealth of information pried out of the fossil-bearing breccia has increased our understanding not only of hominin anatomy but, also of their behaviour. Swartkrans Cave is unique and significant adaptation, in this respect, because of the rich record it provides of hominin interaction with the environment. This information about hominin adaptation is gleaned first from stone tools, which represent the earliest preserved human technologies in the Oldowan, followed by the slightly more advanced Acheulean as well as younger Middle Stone Age artefacts. Then there are the butchered bones of large mammals, that reflect the dietary behaviour of early humans as well as a number of bone tools used for digging, possibly for edible roots and/or for termites. Finally, there is burned bone from a 1-million-year-old deposit, representing some of the world's oldest evidence for the controlled use of fire.

Laying the groundwork

The history of fossil discoveries in the caves of Sterkfontein Valley goes back to the early part of the last century, but the history of the cave formation processes goes back tens of millions of years. Geologically, the area lies in the 2 800-million-year-old dolomites, a sedimentary rock formed from sea floor sediments when large parts of southern Africa were covered by shallow seas. This dolomite contains high levels of the chemical compound calcium carbonate. Around 30 – 50 million years ago, after the shallow sea receded, groundwater percolating through cracks or joints in the dolomite rock caused dissolution of calcium carbonate, widening the cracks and eventually causing breakdown of the rock. This began the process that would ultimately result in the formation of caverns tens of metres below the surface. Much later, approximately 5 million years ago, these closed caverns finally opened to the surface via narrow shafts. Over thousands of years the caverns became filled with eroded surface soils, rock and sometimes bone and artefacts. As rainwater seeped through the cave roof the dissolution process continued and calcium carbonate residue dripped onto the cave floor. After evaporation the hardened calcite encased the cave floor debris into a cemented deposit called breccia. This deposition and erosion was repeated numerous times before the fossils came to light, mainly through the activities of lime miners. This leaves researchers sifting through a maze of complex natural and man-made processes before they can understand the deposits.

For decades the well-known palaeontologist, Bob Brain, devoted much of his energy to understanding the complex processes of cave formation as applied to Swartkrans Cave, dividing the episodes of deposition and erosion into six infills. The oldest infill, Member 1, is composed of the Lower Bank decalcified sediment and the Hanging Remnant calcified breccia. Member 1 is followed successively by Members 2 and 3. These four deposits entered the cave system from about 2 million years ago until 1 million years ago and have yielded the amazing Swartkrans hominin and faunal assemblages. Member 4 is a younger infill containing Middle Stone Age stone artefacts probably older than 80 000 years. Member 5 is younger still, yielding Holocene period fauna about 11 000 years old.

In 2005 we began a new programme of excavation and research at Swartkrans. The Swartkrans Palaeo-anthropolocial Research Project (SPRP) is a multi-disciplinary, long-term project that is expanding on the work of Bob Brain and others with a new set of research questions. One focus area has been on the oldest Member 1 deposits, which have yielded the fossils of two different hominin species, *Homo ergaster (erectus)* and *Australopithecus robustus*, and which provides an important opportunity to



Above: Oldowan flakes from Swartkrans. The Oldowan assemblage is characterised by small non-standardised flakes. Quartz, readily available around the cave, was the primary choice of raw material reflecting the expedient behaviour of the tool makers. Raw material was rarely transported more than a few kilometres. Image: Jason Heaton

An assemblage is the archaeological term that means a group of artefacts found in association with one another, in other words, in the same context.

An artefact is any object made or modified by a human culture.

interpret early hominin behaviour. The production of stone tools is a particularly interesting behavioural marker.

Earlier Stone Age: Oldowan or Acheulean?

The knapping process, removing flakes from a core by striking it with a hammerstone, is often used to measure the cognitive advances in human evolutionary development. The brain expansion of hominins prior to the emergence of *Homo sapiens* increases cognitive potential and certainly seems to correlate with early advances in technological complexity. The earliest known stone tools, recovered from Gona in Ethiopia, date to almost 2.6 million years old. This industry is named the Oldowan because it was first found by Louis and Mary Leakey at Olduvai Gorge, Tanzania. Oldowan artefacts are the simplest tools made by early hominins. Flakes used for cutting and scraping were removed from a core, leaving a sharp edge that could also then be used as a tool.

Working out who made these tools is difficult; many researchers think that early *Homo* produced the first tools while others believe that *Australopithecus* were also able to do so. What is clear is that *Homo* was certainly responsible for the advancement of technological methods.

Just under 2 million years ago a new species emerged, *Homo ergaster*, considered by many to be an early African version of *Homo erectus*. Within a couple of hundred thousand years *Homo ergaster's* tool kit suggested the production of more complex artefacts in the form of bifacially flaked handaxes and cleavers. These tools, referred to as the Acheulean industry, required a greater degree of cognition because the maker needed to be able to 'see' the finished product as it was being made. This requires abstract thought, an important aspect of human cognition.

Brain recovered close to 300 stone artefacts during his excavations of the 1.8/1.7-million-year-old Lower Bank of Member 1. But the assemblage contained very few diagnostic pieces so it was not possible to determine its chronological position within the Earlier Stone Age. Our goal was to expand the sample size and conduct a technological analysis of the artefacts to determine if the hominin species were making Oldowan or Early Acheulean tools. The renewed excavations have increased the number of stone tools found to over 1 000 artefacts. So far there is no evidence of Early Acheulean production methods. All the flakes reflect simple knapping with little standardisation.

The significance of this is that it was generally believed that it was the use of Acheulean tools that represented the change to systematic butchering of carcasses by early *Homo*. However, the Swartkrans Member 1 tools provide additional evidence that Oldowan tool makers butchered large mammals. Recovered along with ▷▷

Top: Acheulean handaxe made on quartzite raw material. The production of these tools required much more skill and cognitive ability than the previous Oldowan tools. The symmetry and shape of these tools were reproduced throughout the Old World, but the oldest handaxes are found in Africa indicating the traditions developed here and were transferred to Asia and Europe. Image: Jason Heaton

Above: Casts of Acheulean cleavers recovered from the Sterkfontein Valley. Residue analyses on the cutting edge of the original artefacts imply these were general purpose tools as both plant and animal residue were identified. Image: Jason Heaton

Cutmarks on a limb bone from a carcass butchered using stone tools. Both the butchering and the production of the stone tools were done by student participants. These types of replication experiments provide important information for interpreting hominin behaviour. Image: Jason Heaton

Above: Middle Stone Age flakes from Swartkrans. Image: Jason Heaton

Left: Examples of Middle Stone Age cores. Radial (L) and preferential (R), both quartz. Image: Jason Heaton

Below left: Middle Stone Age radial core. Image: Jason Heaton

Symbolic behaviour is the ability to use or respond to a system of significant symbols. The significance of this behaviour is that individuals were able to understand and communicate about their environment through the use of symbols such as rock art, decorations and artefacts such as jewellery. In this lie the origins of the complex thought and behaviour that characterise modern humans.

the artefacts are cut and precussion marked bones.So it appears that, at 1.8/1.7 million years ago, *Homo ergaster* at Swartkrans was still using the 'old-fashioned' Oldowan tools and, importantly, using them for butchering large mammals.

The Middle Stone Age: changing tool types and anatomically modern humans

Because the previous work at Swartkrans focused on the older deposits of Members 1, 2 and 3, expanding our understanding of hominin behaviour between 2 million and 1 million years ago, Member 4 was never fully explored. However, Bob Brain excavated a test trench in the upper, superficial layers of the deposit and recovered several hundred Middle Stone Age (MSA) artefacts.

The MSA, a period dating from approximately 300 000 years ago to 50 000 years ago, is characterised by a change in stone tool type. Handaxes and cleavers, which had been part of the tool kit for well over a million years, are replaced with lighter, more standardised flake and blade industries.

The other important characteristic of the MSA is the appearance of anatomically modern *Homo sapiens* along with the eventual emergence of modern human behaviour. Human fossils recovered by Tim White and his team at the site Herto in Ethiopia, dated to 160 000 years ago, indicate a physically modern individual. The interpretation of modern human behaviour within or just following the MSA is still a much debated subject. However, recent discoveries such as engraved ochre from Blombos Cave in South Africa support the argument that these modern-looking *Homo sapiens* were exhibiting symbolic behaviour by 70 000 years ago.

This behaviour is also demonstrated in the technological sophistication of the stone tools. One innovation was the development of prepared core technology. This is essentially a manufacturing process in which a core is prepared by shaping it and removing small flakes from the edges and then striking off a preferred flake. This allowed the tool maker to create flakes of a predetermined size and shape. A second innovation was blade production, in which blade banks were manufactured producing large quantities of very sharp, straight cutting edges. The banks were then used for an array of tool types.

The Swartkrans stone tools and human development

As only limited research has been conducted on the MSA in the Cradle of Humankind region prior to the Swartkrans work, this significant period in human development is only beginning to be documented in the area. Because the MSA sediments are deposits that have washed into an underground cave rather than sediments that arose where the hominins were living at the time (primary occupation layers), we are focusing on the site formation processes that preserve the tools. Our goal is to identify the technological nature of the stone artefacts and to determine how they relate chronologically to other MSA assemblages.

The surface excavations have produced over 4 000 MSA artefacts,

University of the Witwatersrand archaeology student in Member 4 surface excavation. New technology such as a laser EDM (electronic distance meter) allows us to record an X, Y and Z coordinate for each artefact recovered. This provides more detailed information concerning the position of artefacts within the deposit. It also will allow us to create a 3D image of the excavation and recovered artefacts. Image: Morris Sutton

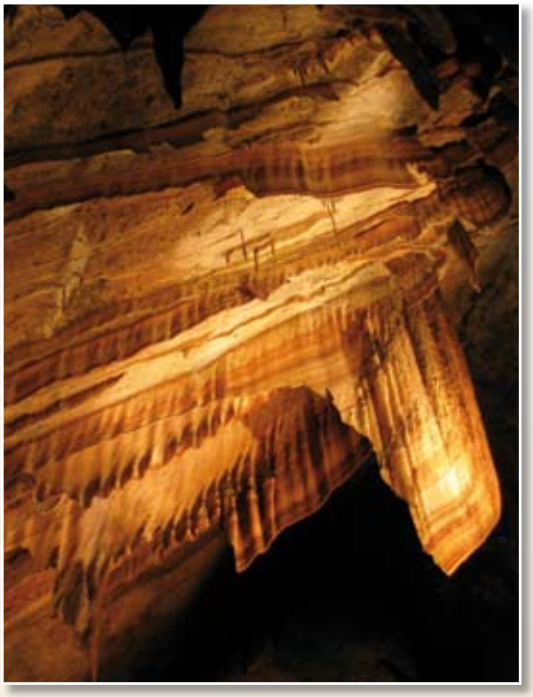
making the assemblage the largest in the Cradle area. The primary tool types reflect core preparation for preferred flakes, as well as blade production, both of which are established MSA techniques. The composition and condition of the assemblage can tell us much about site formation. A near-complete size range of flakes and blades are represented in the assemblage. Additionally, 55% of the assemblage is small flaking debris – waste material that is produced during the knapping process. These two indicators confirm a high level of 'site capture', meaning a natural action such as erosion did not wash away parts of the assemblage. Furthermore, the artefacts show very little abrasion or edge damage. Collectively, these observations suggest little or no trampling and rapid burial, as well as minimal movement of artefacts within the deposit after their deposition.

Another important aspect of this assemblage is the high number of retouched pieces. Retouching is a process whereby the tool user re-sharpens the flake or blade with light blows or by pressure. This removes small flakes from the edge, creating a new, sharp cutting or scraping surface. Roughly 12% of the flakes and blades over 2 cm have been retouched. This shows that some type of tool maintenance activity was taking place at the site. What is missing from the assemblage are proper points (pointed flakes) that are presumed to have been used as projectiles. The absence of these pointed flakes in this MSA assemblage suggests the site does not include obvious hunting activity. Perhaps the assemblage reflects post-hunting activites such as butchering, but the lack of bone preservation in the deposit prevents us from testing this hypothesis. However, many of the retouched pieces are notched and denticulated (with tooth-like projections) scrapers, which represent other kinds of activity.

Newest discoveries: where we are now

An exciting result of our Member 4 excavations has been the discovery of two previously unknown deposits beneath the MSA levels. Due to an accidental formation process we can access the north face of the Member 4 deposit 10 m below the surface. Here, the dolomite has eroded forming a small cavern that accumulated sediment under the roof overhang. Excavations were conducted in this exposed north face of the talus. After 10 – 15 cm of excavation a flowstone was uncovered that capped the deposits on which the overlying MSA deposit rests.

This capstone has been dated, using a Uranium-Thorium radiometric method, to 110 000 years ago, establishing a maximum possible age for the MSA artefacts. There were no MSA artefacts found beneath this flowstone, but we immediately began finding bone, including fossils of *Australopithecus robustus*. The latest date for the appearance of *Australopithecus robustus* is believed to be around 900 000 years ago, which provides clear evidence that the underlying talus cone is much older than the MSA deposit resting on the flowstone. Thus far, five *Australopithecus robustus* fossils



An example of a flowstone from the Gunns Plains Cave, Tasmania. Image: Wikimedia commons

A flowstone is a sheetlike deposit of calcite formed where water runs down the walls or along the floors of a cave.

and a large assemblage containing the remains of many other animal species have been recovered from the Member 4 underground talus cone. Continued excavations have also revealed a second deposit underlying the talus cone. This stratigraphically older deposit has also yielded fossils.

A technique called fabric analysis was used to clarify the formation processes involved in these two underlying deposits and was carried out on elongated stone pieces present in the sediment. Fabric analysis measures the orientation and inclination of the stone in a deposit and can establish flow direction and slope angle. Rocks moving in sediment will orientate their long axis along the direction of the flow. Additionally, the slope of the host matrix will influence the dip or inclination of the stone. Fabric analysis of the two underground deposits reveals the lower deposit flowing in an east north-east direction with only slight inclination, indicating sediment entering from the west and reaching the furthermost end of its flow near the east wall. The overlying talus cone stone, on the other hand, is orientated in a north direction with a 300 – 400° angle. This is what is expected for the north-leading edge of a talus infill entering through an opening above.

This preliminary analysis supports the view that the two underground ▹▹

International field school students excavating the de-calcified Lower Bank of Member 1 at Swartkrans.
Image: Jason Heaton

deposits resulted from two different openings into the Swartkrans Cave system. The talus material entered from directly above forming a cone, while the lowest deposit entered from the west (from the direction of the Lower Bank of Member 1) and levelled out as it passed under the roof. As a result, our work on the MSA deposit has revealed that Member 4 is not one unit, but is composed of material from at least three different depositional episodes, including a previously unknown extension of the Member 1 Lower Bank and a hominin fossil-bearing talus cone infill beneath the MSA surface.

Future research: where we are going

The critical issue of dating the fossil-bearing caves in the Cradle of Humankind has been a great challenge for several decades. In the past, the age of recovered artefacts and fossils was based on comparing the assemblages with material from East Africa where volcanic tuff layers allow for Potassium-Argon radiometric dating, which uses the decay rate of potassium isotopes relative to argon to measure elapsed time. However, in the last couple of decades new methods of dating have been successfully applied to the South African deposits.

One of our future projects involves Uranium-Lead radiometric dating. This method relies on the decay rate of Uranium 236 into Lead 206. By comparing the quantity of Uranium 236 with Lead 206 an estimated age can be determined. This method will be applied to several flowstones present in the cave system. Dating the calcium carbonate layers can set maximum or minimum dates for fossils above or below them.

Another dating method planned for the Swartkrans deposits involves cosmogenic nuclides. Cosmogenic nuclides are isotopes that are produced by interaction of cosmic rays with the nucleus of the atom. Based on the knowledge that the Earth's surface material is being bombarded with cosmic radiation, which stops once something is buried beyond several metres of earth or rock, it is possible to calculate an age when that burial occurred. This type of method can benefit our research by establishing when these surface deposits entered the cave system.

Another area of research that should provide us with a better understanding of the cave infills is trace element analysis. Inductively coupled plasma mass spectrometry (ICP-MS) is a fast and accurate multi-element analytical technique used to determine the trace elements in samples. In ICP-MS, elemental abundances or isotopic ratios are determined by the mass spectrometry (MS) of ions generated in an inductively coupled plasma (ICP). The identification and analysis of trace element composition could help resolve the problem of differentiation of the Swartkrans Members. The use of ICP-MS to determine the element components of each type of breccia would present a means of making comparisons of breccia from the different depositional episodes (Members). This would be a new approach to deciphering some of the issues relating to the infilling processes of the cave system.

Our renewed excavations at Swartkrans have resulted in answers to several questions regarding both the artefacts and the site formation processes, but inevitably they have also raised other questions. However, as advances in science continue to provide new methods to interpret the complex processes of both the cave formation and the fossil contents we expect Swartkrans to continue to provide stimulating answers about our evolutionary past. □

An inductively coupled plasma is a type of plasma source where the energy is supplied by electrical currents that are produced by electromagnetic induction, that is by time-varying magnetic fields.

A plasma, in physical science, is a partially ionised gas in which a certain proportion of electrons are free, rather than being bound to an atom or a molecule.

Morris Sutton has completed the requirements for his PhD in palaeoarcheology at the University of the Witwatersrand and is beginning a research position at the Institute for Human Evolution based at Wits.

Were our early ancestors murderers and head-hunters? A prehistoric detective story

It is commonly believed that early hominins were powerful hunters, capable of killing any of the many other animals that co-existed with them, including the predators. However, **Bob Brain** tells us that the fossil record was not all that it first seemed.

The Taung limestone mines – the beginning of the story

When Raymond Dart left Australia in 1923 to take up the position of Professor of Anatomy at the University of the Witwatersrand, one of the first things he did was to set up an anatomical museum. To do this, he needed specimens and he invited his students to bring in anything interesting that they came across. Josephine Salmons, the only woman student in his class, arrived with the fossilised skull of a baboon from a lime mine at Taung, Northern Cape.

This was an exciting find and Dart consulted his colleague Dr RB Young, a geologist who was involved with the lime mining operations at Taung. Dart asked Young to send any further fossils that were found directly to him. In 1924, two large boxes of fossils arrived at Dart's door. When he examined the fossils in this box, Dart was amazed to find that one of them contained the skull of a creature that was neither human nor ape, but somewhere in between.

The skull was preserved in limestone and Dart spent months painstakingly chipping it out and found that it was the skull of a child with a full set of milk teeth, probably about ten years old in human terms, when it died. Dart then prepared a detailed description of the skull, naming it *Australopithecus africanus*, 'the southern ape of Africa'. He noted that it had many features that were intermediate between those of humans and the apes. This conclusion was confirmed when Robert Broom described the first adult specimen of *Australopithecus* from the Sterkfontein cave, 11 years later.

Hominins as hunters?

But it was not only the anatomical features of *Australopithecus* that had fascinated Dart from the beginning. The people working at Taung found large deposits of fossil bones, which Dart thought were part of a 'kitchen midden' or rubbish heap of the ape-men who had used the cave for shelter. ▹▹

The Taung child

The Tuang child is one of the most important fossil finds of the 20th century. Raymond Dart's publication of his find, in 1925, firmly established *Australopithecus africanus* as the ancestral 'missing link' between apes and humans. He also challenged some of the prevailing views on human evolution, which held that large brains were the key evolutionary feature that identified human, rather than ape, ancestry. In contrast, Dart believed that a small-brained, but already bipedal species of hominin was significant in human evolution.

He highlighted other features of the Taung child's morphology (form and structure) that were important and interesting. Brain size played an important part – he noticed that the brain size indicated by the fossil was too large to be a fossil monkey or a baboon. This immediately suggested that the fossil was something new and unknown. However, perhaps more important than the size of the brain was the structure of the brain. The inside of the fossilised skull was marked with impressions of the surface of the brain and preserved details of the convoluted gyri (raised ridges) and sulci (grooves) of the brain's cerebral cortex and other details. Fortunately Dart had a background in neuroanatomy (the anatomy of the nervous system and brain) and he could immediately see that the Taung fossil showed human-like or 'advanced' brain structure – and so function – in comparison with apes.

The second feature was that the canine teeth were smaller and projected less than would be expected in an ape. When the lower jaw was separated from the cranium much later in the process Dart was able to confirm that the fossil was not an ape and was more closely related to humans. In particular, the Taung child did not have the large projecting face (called prognathism) that an ape would have.

The final important feature was the position of the foramen magnum – the opening through which the spinal cord leaves the skull to enter the vertebral column. The foramen magnum was positioned relatively far forward on the base of the skull. This showed that the head was balanced on top of a vertical trunk, in other words the Taung child was almost certainly bipedal.

It was Dart's description of the Taung child that led to the identification of a series of morphological features for a group of early hominins that became known as the australopithecines. These are members of the earliest-known family of human ancestors.

Eleven years later, Robert Broom described the first adult australopithecine from the fossil site at Sterkfontein.

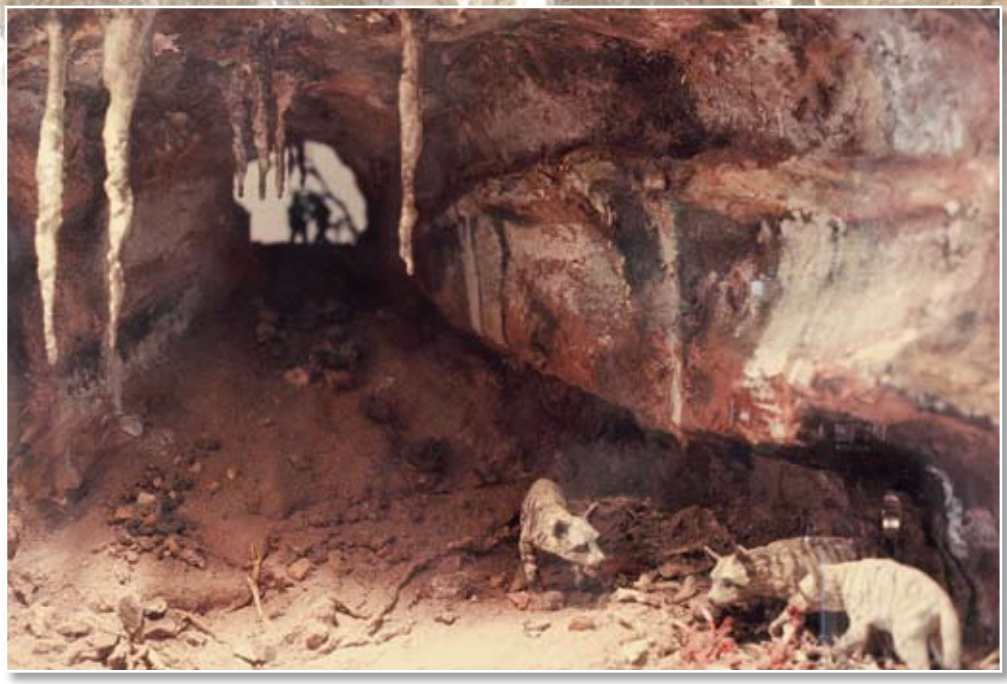
Top right: Lateral and front views of the Taung child.

Middle right: Raymond Dart, with the recently discovered Taung child skull in 1924.

Image: The Witwatersrand University School of Anatomical Sciences.

Right: The walkway to the Sterkfontein excavation site.

Image: Bridget Farham



Above: Raymond Dart in 1965 with a block of richly fossiliferous breccia from the Makapansgat Limeworks Cave. It was on the basis of fossils from this site that he developed his concept of the Osteodontokeratic Culture of Australopithecus.

Above left: A reconstruction of what the Makapansgat Limeworks Cave may have looked like as the bones were accumulating there, about three million years ago. In the foreground are striped hyenas, whose remains have been found among the fossils and which were probably responsible for bringing bones back to the cave.

Left: A breccia wall at the Swartkrans fossil site. Image: Bridget Farham

An osteodontokeratic culture is one that is based on tools made of bones and teeth.

Travertine is a sedimentary rock. It forms as calcium carbonate is deposited from the water of mineral springs that are saturated with dissolved calcium bicarbonate.

A local school teacher, Wilfred Eitzman, sent Dart many fossil bones from the Makapansgat Limeworks Cave in the northern Transvaal. The bones included many that appeared blackened and burnt, suggesting the use of fire. In 1925, Dart concluded that Makapansgat had been 'a site of early human occupation', but he did not visit the site until 20 years later when a Wits University student expedition, led by Phillip Tobias (who would ultimately succeed Dart as Professor of Anatomy), showed that new fossils could be found there.

When Dart first visitied Makapansgat he immediately recognised the importance of the site as a potential early hominin locality and employed several people to sort the lime-miners' dumps. These excavations unearthed the first Makapan hominin fossils, which Dart named *Australopithecus prometheus*. He assumed that these australopithecines had been responsible for burning the blackened bones found in the deposit.

However, subsequent research failed to confirm the presence of free carbon in the bones, which would have been present had the bones been burnt, and Dart and his colleagues concluded that the blackening was caused by the presence of manganese dioxide.

The mining operations at Makapansgat had brought to light a layer of 'grey breccia' low down in the sequence of the cave's deposits that contained hundreds of thousands of fossilised bones.

Dart arranged for the extraction of over 7 000 of these from their travertine matrix and worked out which skeletal part was represented and the kinds of animals that each bone came from.

He found that most were from antelope; many came from quite large species and there was a remarkable disproportionate representation in skeletal parts. For instance, in the antelope the lower end of the humerus was found ten times more commonly than the upper end of the humerus (the long bone in the front leg). In other animals, such as baboons and hominins, it was common to find only the skull, with no trace of the rest of the skeleton.

Above: An overhanging wall at the Swartkrans site, showing the stratigraphic layers. Image: Bridget Farham

Dart explained these curious discrepancies by proposing that the pile of bones had resulted from the exploits of the ape-men. He saw them as powerful hunters who were capable of killing the most dangerous animals of the time. He believed that they brought bones back to their cave shelters, but only those parts of the skeleton that would have been of use as tools and weapons. The lower end of an antelope humerus, for instance, made a useful club and so it was retained, while the upper end, together with various other parts, were discarded at the site of the kill. He developed the concept of an 'osteodontokeratic culture', which explains how a large variety of bones would have been used in various ways. In presenting his concept of the 'the predatory transition from ape to man', he used powerful prose:

'On this thesis man's predecessors differed from living apes in being confirmed killers: carnivorous creatures that seized living quarries by violence, battered them to death, tore apart their broken bodies, dismembered them limb from limb, slaking their ravenous thirst with the hot blood of victims and greedily devouring livid writhing flesh.' (Dart, 1953)

Because only the skulls of fossil hominins were represented, Dart proposed that they had been 'head hunters' and 'professional decapitators'. He presented his ideas in a series of 39 publications on the topic between 1949 and 1965.

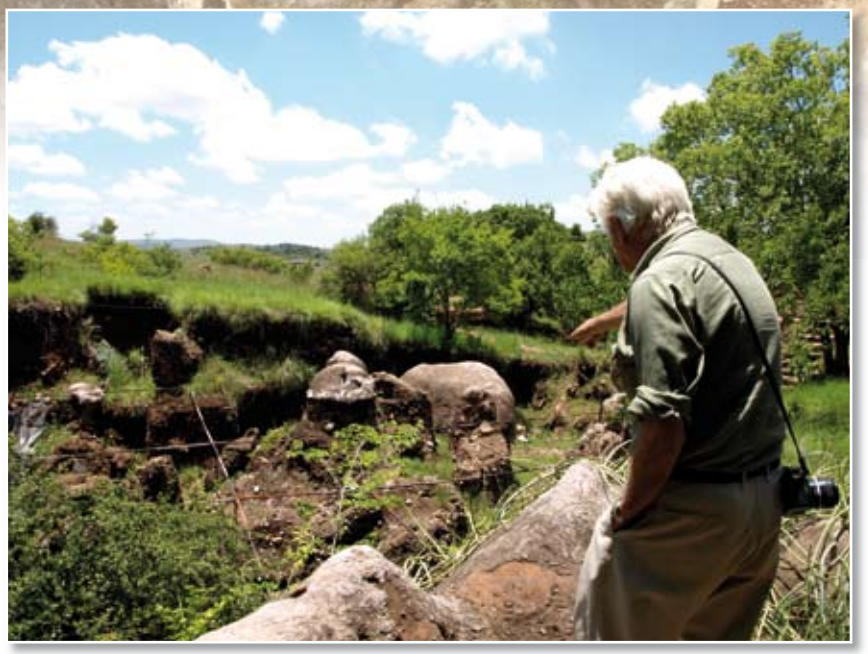
Throughout this project, Dart's style of writing was dramatic and forceful, unlike that normally encountered in serious scientific publications. I asked him why he had chosen this particular approach and he replied without hesitation: 'That will get them talking!' and talk they certainly did! Dart's ideas generated an enormous amount of interest and controversy in scientific and lay circles alike and provoked various people, including myself, to re-evaluate his claims.

At the time Dart first presented his conclusions on the osteodontokeratic culture, I was busy with my PhD project on the geology of the caves from which the hominin fossils had come. I developed three ambitious goals at the time: the first was to analyse, as Dart had done, the fossil accumulations from all the other hominin-bearing cave sites known at the time; the second was to excavate one of these sites myself, in order to build up a meticulously documented fossil assemblage, and the third was to investigate all the factors responsible for bone accumulations in caves. I had to wait until 1965 for this opportunity to materialise, when I was appointed palaeontologist at the Transvaal Museum in succession to Robert Broom and John Robinson, both well-known palaeontologists.

I then started an intensive investigation of the Swartkrans Cave that continues to this day and has produced a sample of about 240 000 individual fossil bones, each precisely documented as to its stratigraphic relationships. ▹▹

Stratigraphy is the investigation of the composition of the layers of the Earth. It is used in relative dating, using the principle of superposition.

Superposition is the principle that under stable conditions, strata on the bottom of a deposit were laid down first and so are older than the layers on the top.



Above: Bob Brain at Swarkrans. Image: Bridget Farham

Left above: A partial skeleton of an ape-man, Australopithecus robustus *from Swartkrans. Although skull pieces of these hominins were common in this cave deposit, other parts of the skeleton were very rare, leading to 'the mystery of the missing bodies'.*

Left middle: Part of the skull of a juvenile hominin from the Swartkrans Cave, with two holes in its parietal bones. The spacing of these holes is matched closely by that of the lower canines of a fossil leopard from the same deposit.

Top and above: A reconstruction in the Transvaal Museum of the Swartkrans ape-man child suggesting that it had been killed by a leopard and then carried to a feeding lair in the cave. The lower canines of the leopard are in the back of the child's head, while the upper canines are in its face.

Not predators but prey

When I started to analyse other ancient and modern fossil bone assemblages, it soon became clear that skeletal disproportions were common and were the inevitable result of the fact that some skeletal parts survive destructive treatment better than others. As an example, in a sample of 2 373 modern goat bones discarded by Nama peoples around their Namib Desert villages and then chewed by their dogs, I found 87 distal (away from the point of origin) humerus pieces, but not a single proximal (close to the point of origin) end. The reason was clear: while the distal humerus is a solid, dense piece of bone with a relatively high specific gravity, this was not true of the upper end, which has a fragile spongy structure with a much lower specific gravity, and is easily destroyed for the marrow it contains. Interestingly enough, the overall survival of goat skeletal parts in the Namib sample closely mirrored what Dart had found in his sample of antelope bones from Makapansgat, so it was no longer necessary to assume that early hominins were deliberately chosing these bits of bone. In other words, the fossils simply represented what was left of the bones after they had been discarded and broken up.

Before publishing anything on this finding, I showed the Namib bones and findings to Dart and explained the implications for his osteodontokeratic cultural concept. It was obvious that these results undermined the basis of Dart's theory, and for about ten minutes he was taken aback and perplexed. But after this initial dismay, he became increasingly enthusiastic, saying 'this is wonderful – now at last we are getting closer to the truth'. Rather than condemning this young upstart who was destroying his cherished concept, Dart nominated me for an award. I realised then that he was much more interested in the truth of his investigations than in his status in the scientific hierarchy and that he was one of those rare individuals with true generosity of spirit, particularly in this rather emotional field of human ancestry.

But what about the fact that Dart's fossil antelope skeletons from Makapansgat were so much better represented than were the ape-men and the baboons there? And why were only the skulls of ape-men and baboons found? The same story came to light at the Swartkrans Cave where, although we had remains of over 150 individual hominins, based on parts of their skulls, other bones from their skeletons were almost completely absent.

This became known as 'the mystery of the missing bodies'. Light was thrown on this dilemma when I studied the feeding behaviour of group of captive cheetahs on a game-farm in Namibia. When these cheetahs ate a springbuck or a sheep, they did very little damage to the bones of the skeletons, but when they fed on a baboon of comparable live-weight, they would chew up the entire vertebral column and most of the limb bones,

leaving the skull intact.

It turned out that a primate skeleton is simply much more chewable and susceptible to damage by a carnivore than is the skeleton of a comparable antelope. Another insight into this came to light at Swartkrans when we found that the back of the skull of a child had two small round holes in its parietal bones, the bones at the back of the skull. I noticed that the distance between these holes was matched very closely by that of the lower canines of a fossil leopard from the same part of the cave.

My interpretation was that the child had been killed by a leopard, probably by the usual neck-bite, and then picked up with the lower canines in the back of the head and the upper ones in the child's face. It was then carried into the lower parts of the cave, and consumed there.

The full story

The Swartkrans Cave story that gradually developed as my excavation progressed, was that both our early human ancestors and our relatives, the robust ape-men, were living in an open savannah environment there between two and one million years ago and that they regularly sought shelter near the cave's entrance, probably on cold winter nights.

Here they became the prey of leopards and sabre-toothed cats, who dragged our ancestors into the deeper parts of the cave, where they were eaten. The robust ape-men disappeared from the scene about a million years ago, while our own ancestors experienced a steady enlargement of their brain-size, providing them with improved intelligence and technology, such as the management of fire. The earliest evidence of the use of fire has come from this remarkable Swartkrans Cave, as well as evidence for the use of bone tools. These consisted of pieces of longbones, that showed remarkable wear and scratchmarks. We were able to reproduce this pattern of wear experimentally when we used fresh bone pieces to dig edible tubers from the Swartkrans hillside.

When Raymond Dart was over 90 years old, I showed these bone tools to him and although he was almost blind, he felt their tapered points between his fingers with great enthusiasm. Then he said: 'Brain, I always told you that *Australopithecus* made bone tools, but you would not believe me. What were these used for?' I replied that I thought they had been used for digging in the ground. His mouth fell open in total disbelief. 'That is the most unromantic explanation I've heard of in my life!' he said. Then he grabbed the longest of the bone tools in his hand and thrust it into my ribs, saying: 'Brain, I could run you through with this!'.

I do not believe that Dart ever gave up his favourite concept of our ancestors having been murderers and head-hunters. In fact, he often said to me: 'Never let the facts get in the way of a good story!' □

CK (Bob) Brain is the Emeritus Curator of the Transvaal Museum. He was director of the museum from 1965 to 1991. During that time the museum became one of the most scientifically productive institutions of its kind in Africa. He planned and put together the Life's Genesis 1 and Life's Genesis 2 display halls, which have been visited by several million people over the years. He remains keenly interested and involved in the excavations at Swartkrans.

Above: The entrance to the Swartkrans cave complex as it is now, after many years of excavation. Image: Bridget Farham

Above left: A view of the Swartkrans Cave excavation, as it progressed towards the north wall in 1980.

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Acknowledgements

I would like to thank Dr Bridget Farham for her invitation to me to contribute an article for *QUEST – Science for South Africa*. I do so with pleasure and wish this journal every success in the future. My thanks also go to Travis Pickering and Morris Sutton for continuing with the Swartkrans Cave investigations with such enthusiasm and care. Finally, it was from Raymond Dart that I received much of the inspiration for the research I have done in the course of my career.

The steel structure for the HESS Phase II dish.
Image: HESS Erlangen Group

Gamma-ray astronomy in southern Africa: **the quantum leap from HESS to CTA**

Okkie de Jager and **Louis Venter** discuss the expansion of gamma-ray astronomy in southern Africa.

Cerenkov radiation

Cerenkov radiation is electromagnetic radiation that is emitted when a charged particle, such as an electron, passes through an insulator at a speed that is greater than the speed of light in that medium. This blue glow was first seen in nuclear reactors and the mechanism was identified by Pavel Chernkov in 1934.

The Cerenkov effect seen in a nuclear reactor.
Image: Wikimedia commons

New astronomical discoveries and developments in southern Africa

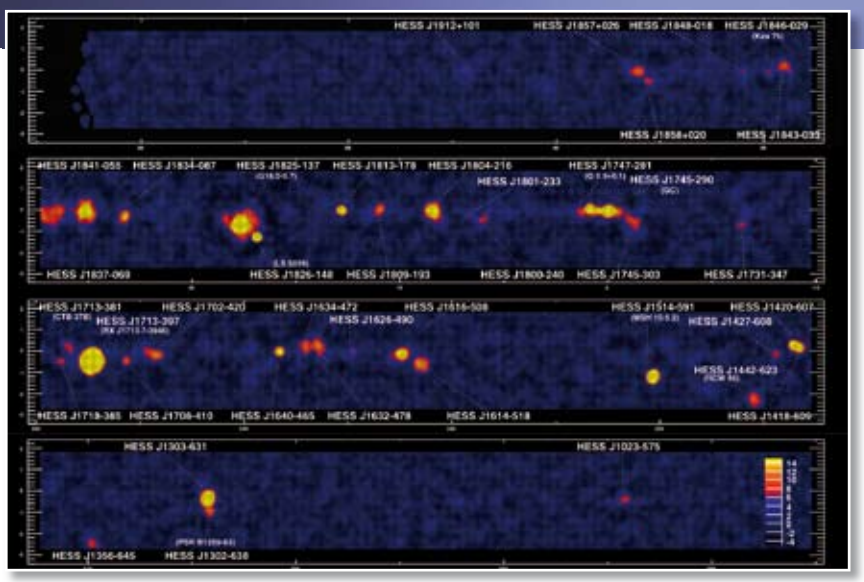
The name HESS stands for **H**igh **E**nergy **S**tereoscopic **S**ystem, and the name is also intended to pay homage to Victor Hess, who received the Nobel Prize for Physics in 1936 for his discovery of cosmic rays. This telescope array consists of four 12-metre diameter optical reflectors and is located in Namibia, about 100 km south of Windhoek. It is operated by a consortium of European Institutes, with universities in Namibia and South Africa as the only non-European partners. HESS is currently being upgraded to HESS II, which adds a 30-metre diameter optical reflector at the centre of the current array of HESS telescopes in order to increase both sensitivity and its range of energies.

Recently HESS was listed as one of the ten most successful observatories worldwide, with the Hubble Space Telescope listed third, based on best scientific performance. The northern hemisphere equivalents of HESS are MAGIC I and II. The high energy community is now working towards a dramatic step forward in sensitivity by developing the Cerenkov Telescope Array (or CTA), which is expected to consist of more than 100 gamma-ray telescopes, covering an effective collection area of several square kilometres. Showing this united effort, CTA was recognised as one of Europe's flagship projects under the name of the European Strategic Forum for Research Infrastructures (ESFRI). The radio SKA (Square Kilometer Array), which is being actively developed in South Africa, is also listed together with CTA as one of the ESFRI flagship projects in the astronomy and astroparticle section.

These developments represent a quantum leap in planning, with at least 100 new telescopes being developed to replace the current four.

What has HESS shown us?

HESS allows scientists to explore gamma-ray sources with photon energies a million times larger than the energies of visible light photons. So, while visible light photons have energies around one electron volt (1 eV), the gamma-ray energies probed by HESS have energies around 10^{12} eV or 1 TeV (tera electron volt).



The different sources of high energy gamma-ray sources – these consist mainly of resolved pulsar wind nebulae, a few supernova remnants, one or more microquasars and a number of unidentified gamma-ray sources. Notice how tightly these gamma-ray sources are confined to the galactic plane, whereas stars visible to the naked eye are much more scattered, giving the relatively wide band of stars known as the Milky Way.

Image: HESS contributions to the International Cosmic Ray Conference 2007

The production of such very high energy gamma-rays requires violent processes in hot spots in the Universe. When such a gamma-ray enters the Earth's atmosphere, it causes a so-called electron-photon cascade (a multitude of gamma-rays, electrons and anti-electrons called 'positrons') with associated Cerenkov radiation in the form of a bluish light disc with a diameter up to 300 m, but a thickness of only about 1 m. The Cerenkov light is emitted by the electrons and positrons because these relativistic particles (also called 'leptons') move faster than the speed of light in air. This flash of bluish light is then detected by large mirrors (typical diameter of 12 m or larger) and resolved with pixelated high-speed cameras with effective 'shutter' speeds of a billionth of a second (to focus on the 1 m thickness of the light disc).

HESS was constructed in Namibia near the Gamsberg mountains because of the excellent optical quality of the site. The first of the four telescopes of phase I of the HESS project went into operation in Summer 2002, and all four telescopes were operational in December 2003. You can learn all about the telescope itself on http://www.mpi-hd.mpg.de/hfm/HESS/.

What's new from HESS?

The Milky Way in very high energy gamma-rays

HESS was the first telescope to resolve a population of very high energy gamma-ray sources along the galactic ridge of the Milky Way. Since then we have discovered more sources along the galactic plane, which are shown above. The four panels show the details of the individual sources.

We detected a Wolf-Rayet binary, a microquasar, a binary radio/X-ray pulsar, a few supernova remnants (SNR), a multitude of pulsar wind nebulae (PWN), and a few unidentified sources or 'dark accelerators'.

What HESS can tell us in the future: black holes and the speed of light

HESS is able to provide information about the physics of black holes. For example, by examining the event horizon of the black hole in the Fanaroff-Riley[1] (FR1) galaxies, HESS has shown that there is a region around the black hole that can accelerate particles to ultra-relativistic energies. In physics a particle is called ultra-relativistic when its speed approaches the speed of light.

Is the speed of light constant? According to Einstein, it is – in empty space. However, if we were able to show that the speed of light is not constant, this would change our whole understanding of the physical world. Quantum physics predicts that there will be deviations from the speed of light at what is called the Planck energy.

The Cerenkov Telescope Array will be able to detect gamma-rays from distant cosmological sources. As with HESS, we also expect to detect rapid bright flares from these sources with CTA and if the speed of light depends on the energy of the photon (as predicted by quantum gravity), then these flares would be dispersed in ▹▹

1. Named after Bernie Fanaroff – the Project Leader of the South African Square Kilometer Array. Bernie and Riley discovered these off-axis galaxies several decades ago.

Definitions

Wolf-Rayet binary: these stars are massive objects on the brink of a massive supernova explosion and have some of the hottest surfaces in the Universe.
Microquasar: this is radio and/or X-ray emitting binary system and is the smaller cousin of a quasar – they have strong radio emissions, and an accretion disc that surrounds a compact object, which is either a neutron star or a black hole.
Accretion disc: this is a structure that is formed by the diffuse material that is in orbit around a central body, such as a young star or a black hole.
Supernova remnant: this is the structure that remains after a massive explosion of a star as a supernova event, which has an expanding shock wave at its boundary. It is formed from the material that was ejected in the explosion and all the interstellar material that it sweeps up as it moves.

An image of a supernova remnant. Image: NASA

Pulsar wind nebula: a nebula that emits a specific form of electromagnetic radiation, called synchotron radiation. Early in their evolution, they are often found inside the shells of supernova remnants. The well-known crab nebula is an example of a pulsar wind nebula.

The crab nebula. Image: NASA

Dark accelerators: these are some of the most exciting phenomena in the Universe. They are objects that are emitting very high energy gamma-rays, but they apparently have no optical or X-ray counterpart.

In physics, the unit of energy in the system of natural units called Planck units is called Planck energy. Max Planck was a German physicist (1858 – 1947) who is considered the father of quantum physics.

The HESS Collaboration photographed in Annecy, France, with the octagonal shaped camera in the yellow frame above the heads of the Collaboration members. This is probably also the world's largest imaging camera. It was built by the same people who built CERN's Large Hadron Collider, since there is a frequent exchange of expertise between CERN-type experiments and very high energy gamma-ray telescopes, such as HESS and MAGIC. Image: HESS Collaboration

time in a predictable way through the energy dependence of the arrival time of gamma-rays. If we do not detect such a dispersion, then we can set experimental limits on the energy dependence of the speed of light and hence limits on the applicability of quantum gravity. With CTA we hope to break through the so-called 'Planck mass' barrier predicted by quantum gravity, since beyond this barrier we should be able to see if this theory is correct.

HESS II

HESS II is a combination of a single dish that has a diameter of about 30 m and the HESS I telescopes. This will provide a telescope that has a light collection area that is significantly larger than the current HESS telescope.

The foundation of HESS II is already completed, while the steel structure for the HESS phase II dish is currently being constructed in Walvis Bay, Namibia.

This HESS phase II telescope will reach a total height of 40 m and have an overall mirror area of more than 600 m^2. This will make the HESS phase II telescope the largest Imaging Air Cerenkov Telescope ever built. The ultra-fast speed imaging camera (also with a shutter speed of a billionth of a second) is enormous.

The Cerenkov Telescope Array

CTA will be to gamma-ray astronomy what the SKA is to radio astronomy. By combining efforts from the teams that worked on MAGIC in the northern hemisphere and HESS in the southern hemisphere, expertise, as well as proven and new technology, will be combined to increase the effective collection area. Thus, CTA will become a SKA in its own right. For example, while we currently have only four telescopes in the HESS array, we expect CTA to contain more than 100 HESS-type telescopes and if the funding is sufficient, the central core will focus on lower energies after larger MAGIC and/or HESS II type telescopes are added. There will be two such telescope arrays: one in the northern hemisphere and another in the southern hemisphere and with more than 100 instead of only four telescopes, project management will become truly international.

The site for CTA

CTA will have a site in both the southern and northern hemispheres. In the south, Argentina, Chile, Namibia and South Africa may provide candidate sites. The Khomas highland (1 800 m above sea level) in Namibia, for example, currently hosts the HESS array of four dishes. Flat areas larger than about 1 km^2 and above 1 500 m are not common in southern Africa. However, the Khomas highland easily fullfils these basic requirements. In South Africa the southern part of the Great Karoo, stretching eastward from about Sutherland to Graaff-Reinet, is the area of the country best suited to dedicated astronomy and may provide suitable sites.

Argentina currently hosts the Pierre Auger Cosmic Ray Observatory, which aims to detect secondary high energy particles and ultra-violet light created by cosmic rays that collide with atmospheric molecules. Medium- to high-altitude sites may be found in the west of this country. Chile, host to many of the world's largest optical telescopes, is also a possibility.

The timeline for CTA

This is the approximate timeline for the CTA:

- Technical design: 2006–2009
- Prototype construction: 2010–2011
- Construction phase: 2011–2018
- Partial operation beginning in: 2013
- Commissioning: 2015/2016
- Full systems in: 2018.

By this time the MeerKAT telescope should be fully operational at the science level as well, so that serious joint searches for dark matter signals and radio/gamma-ray correlations can be performed. The superb photometric, spectroscopic and polarimetric features offered by SALT in the optical telescope domain should help CTA to understand its broad collection of multiwavelength sources (galactic and extragalactic) radiating in the optical domain. □

Okkie de Jager is based in Potchefstroom at the Unit for Space Physics, North-West University. He is the HESS group leader for South Africa, and is active in the identification, interpretation and mathematical modelling of HESS sources.

Louis Venter completed his PhD in High Energy Astrophysics under the supervision of Prof. Pieter Meintjes of the University of the Free State in Bloemfontein. He is currently a Post Doctoral fellow at the Observatoire de Paris-Meudon working on Active Galactic Nuclei within the HESS Collaboration. He also serves on the site selection committee of CTA.

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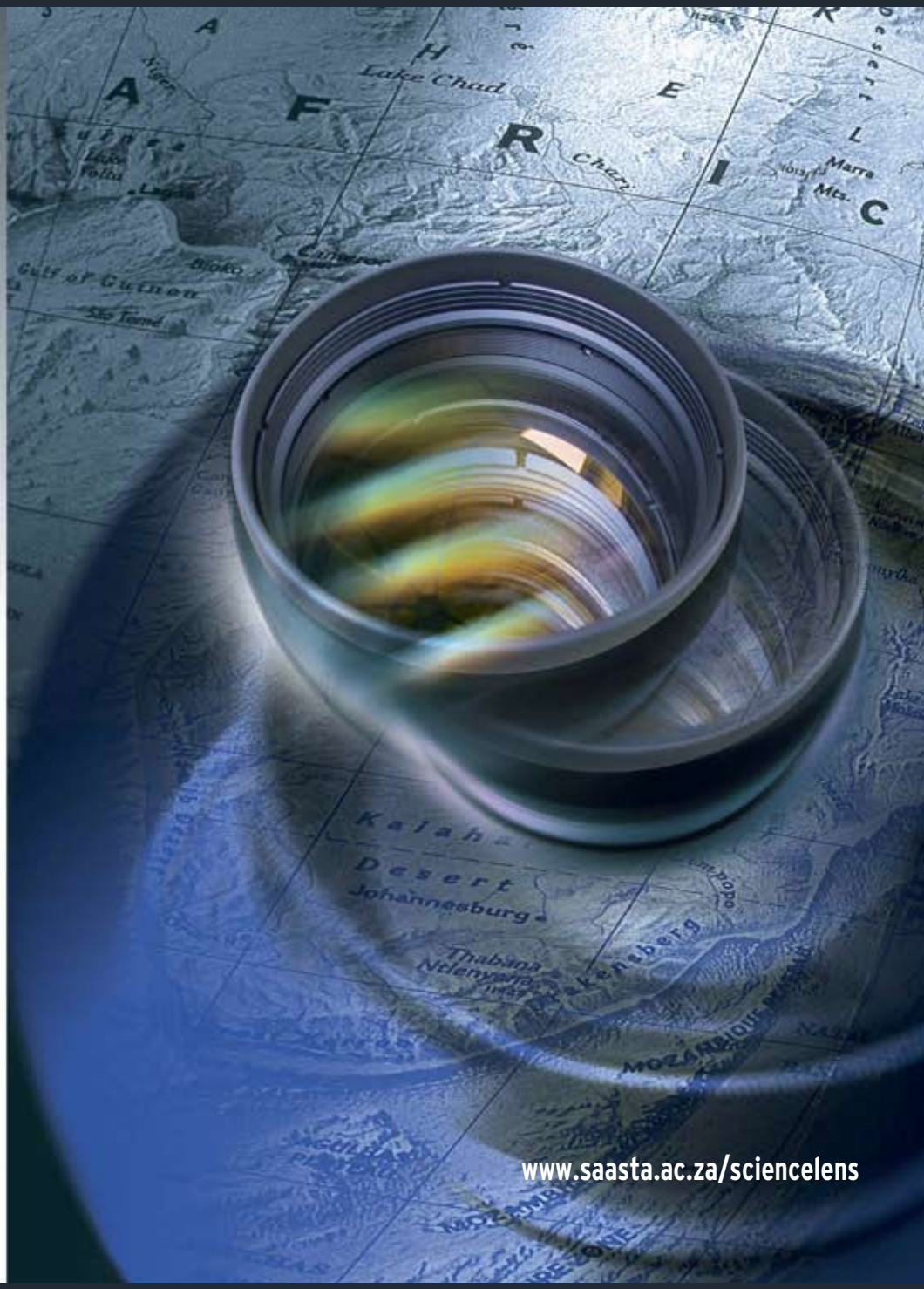

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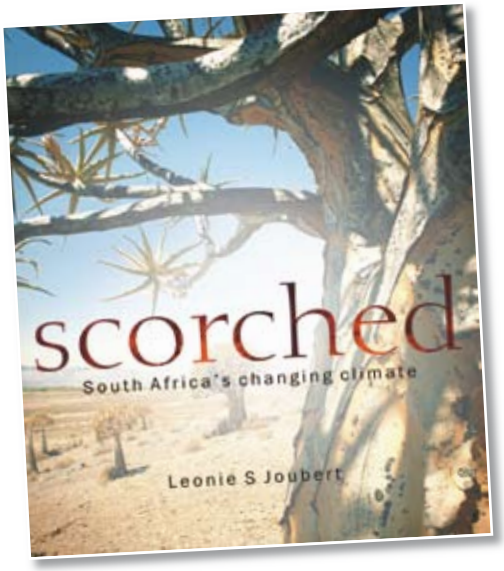
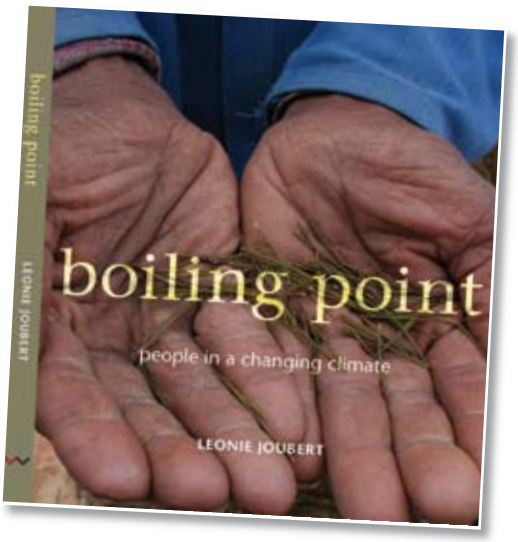
South Africa on the brink: climate change on our doorstep

Above: Lambert's Bay harbour, where a potato factory now clatters away in the pier-side building where a thriving cannery once operated. Image: Leonie Joubert

Above right: Ernest Titus (seated right) and neighbour, Hennie van Wyk. Image: Leonie Joubert





Two major publications should alert us all to the realities of climate change and its impact on our lives. *QUEST* investigates where we are right now.

In 2006, Leonie Joubert's pivotal book *'Scorched: South Africa's Changing Climate'* was published. In it she starts by reminding us that as long ago as 1973 we started to get some idea of how a world without oil would feel. During the 1973 Yom Kippur War, OPEC countries responded to the West's support for Israel by reducing oil supplies to Europe and placing an embargo against the US. Oil prices quadrupled and crude oil supplies fell. Industry in Britain was reduced to working a three-day week, US fuel stations ran dry and recession spread across the world. This, and other oil crises at varying points during the past few decades have reminded us how fragile is our dependence on fossil fuels and also that supplies are not limitless.

The idea of over-exploitation of resources is not new and has spawned a plethora of non-governmental organisations dedicated to raising environmental awareness – focusing on pollution, population growth, food security and environmental degradation generally.

But, as Joubert points out, something else happened in the 1970s. The Northern Hemisphere was warming. However, as she also points out, global warming, or the idea that it might be happening, 'surfaced long before the seventies.' However, the first World Climate Conference was only held in Geneva in 1981 – the year that was, at the time, declared to be the warmest on record and the scientific community called on governments to take action.

Climate is not just an abstract concept – something that determines where you choose to go on holiday according to the amount of sunshine and warmth. Climate is probably the single most important factor in determining whether or not a species can survive in a particular place. In *Scorched* Joubert outlines the probable scenarios as South Africa's climate changes.

As the country becomes warmer, plant and animal species will, in theory, move to areas that are closer to their preferred habitat – either moving north or to higher altitudes. The plant regions of South Africa – desert, forest, fynbos, grassland, Nama-karoo, savannah and succulent karoo – are all expected to 'migrate' – to change their distribution in response to changing conditions. But, just how easily will they be able to do this? Is there enough habitat available in new geographic ranges?

South African scientists have projected – using mathematical modelling – what the landscape will look like by 2050. As Joubert says, the bioclimatic zones will be shifted south-east, with a warming and drying sweeping in from the north-west.

Climate change on this scale will cause warming and drying that are likely to shrink the area that is available to our current biomes to between 38% and 55% of their current combined cover. The greatest losses will be in the western, central and nothern parts of the country. According to the scientists who produced the climate change models, 'These include the virtual complete loss or displacement of the existing succulent karoo biome … an extensive eastward shift of the Nama-karoo biome and contraction of the savanna biome to the nothern borders of the country and its expansion in to the grassland biome.' They also speculate that the fynbos

Above left: Hendrik with his wife, Sanna (seated), daughter-in-law, Raagel (standing) and the family dog Oogies. Image: Leonie Joubert

Above: Hendrik Hesselman has lived as a share cropper, a bywoner, in the Suid-Bokkeveld for over four decades. Image: Leonie Joubert

biome – one of the richest in the world – may lose many species.

The eventual effects on our entire environment will be enormous. Whole ecosystems will be lost and with them the ecosystem services that we depend on – water, fertile soil, space – the very fabric of our world.

You might think that we in South Africa bear little responsibility for global climate change. But you would be wrong. The more affluent parts of South African society are not far behind the high-energy lifestyle of relatively wealthy Americans or Australians. South Africa's middle class per capita production of CO_2 is probably much higher than the national average because of the gross income inequalities in our society. It is balanced out by the large poor population, whose energy demands and CO_2 output are low because of poverty.

South Africa as a nation is responsible for about half of Africa's total greenhouse gas emissions. We have an energy-intensive economy and cheap, but dirty, coal-fired power stations. Our cheap electricity supplies more than half of Africa's requirements and 90% of this comes from burning coal. More than half of that electricity is used in South Africa itself.

The sad fact is that it is the poorest people who will suffer the most from climate change. And Leonie Joubert's next book *'Boiling Point: People in a Changing Climate'* takes up this theme.

According to the UN's Millenium Ecosystem Assessment, the 'negative impacts of climate change will fall disporportionately on the poorest parts of the world – for instance by exacerbating drought and reducing food production in the drier regions – but the build up of greenhouse gases has come overwhelmingly from richer populations as they consume more energy to fuel their higher living standards.'

Meet Ernest Titus and his neighbour Hennie van Wyk. What, you might ask, have these two West Coast fishermen got to do with climate change? In terms of their contribution to global greenhouse gases, very little. But in terms of the impact of climate change on their lives, a lot. Not only do these fishermen have to contend with the new and unfair quota systems, but the very ocean current that brings the species they fish seems to be working against them too.

The West Coast fishery is dependent on the cold Benguela Current, which provides one of the richest fisheries in the world as it moves up the west coast of South Africa. The prevailing south-easterly winds, characteristic of the Cape's summer, cause an upwelling of cool, deep, nutrient-rich waters to the warm surface where algal blooms provide the basis of a complex food chain that ends in the predatory fish and the crustaceans that form the basis of the West Coast fishery. But it would appear that the Benguela Current is changing. As the land warms, so too does the sea and the rate at which it is warming seems to have been accelerating in the past 15 years.

One of the first signs of change was the sardine fishery, which almost failed completely in 2006 in the traditional West Coast fishing grounds. However, it appeared that the sardines had not gone – they simply moved up the coast to Mossel Bay, which saw record hauls. Seabirds, such as the Cape gannet (*Morus capensis*), followed – shifting the population from the Western to the Eastern Cape. Other species, such as the crowned cormorant (*Phalacrocorax coronatus*) and the Hartlaub's gull (*Larus hartlaubii*) have moved their breeding ranges further east. We are already seeing some of the predicted migrations.

On the fisheries front, anchovy is moving east and rock lobster are moving south. Of course there is a fair amount of controversy over what, exactly, is precipitating this change. It could be over-fishing, but there is also a growing feeling that temperature change is a major factor in the changes seen in the Benguela Current, with the loss of the commercially important sardine and anchovy in favour of less commercially important species.

Joubert's second book takes us across South Africa and into the lives of its peoples. Hendrik Hesselman lives in the Suid-Bokkeveld – on the *Dobbelaarskop* farm – where the desert is encroaching on his and his neighbour's farms. Drought in the Free State has damaged the maize industry – with a shortage of ground water exacerbating the situation.

The developed world has had an impact that no-one could ever have predicted on communities on the other side of the planet. In Joubert's words, 'The cycle that brings the *Dobbelaarskop* farm its water is beyond the ownership rights of any body, whether national or private. The same applies to the fish of the Benguela Current, the rain storms of the Free State, the river ways of KwaZulu-Natal, and the groundwater in Sekhukhuneland. They are part of the greater system, the global commons that is supposed to be held in trust for us, by us.' □

Leonie Joubert is a freelance science writer. Scorched: South Africa's Changing Climate *was awarded an honorary Sunday Times/Alan Paton award.* Boiling Point *grew out of the 2007 Ruth First Fellowship.*

Joubert L. *Scorched: South Africa's Changing Climate*. Johannesburg: Wits University Press, 2006.

Joubert L. *Boiling Point: People in a Changing Climate.* Johannesburg: Wits University Press, 2008.

A braai-wood index

Martina Meincken tells us which braai-woods are fine and which are not.

The braai: a favourite weekend activity.

Take any sunny weekend anywhere in South Africa and the smells of burning wood and roasting meat are sure to permeate the neighbourhood, as people light their fires and indulge in our national pastime – the braai.

The wood used is usually bought in the local shop or by the roadside and its choice often depends on individual preference, habit or tradition. But perhaps we should also be looking at the best wood to use to satisfy environmental concerns.

To shed some scientific light on the differences in types of braai-wood, we investigated five wood species typically used in the Western Cape. We looked at their energy content as well as the environmental impact of burning this wood.

The wood is often sold by its common name and the exact species is not known – the species investigated were rooikrans (*Acacia cyclops*), camelthorn (*Acacia erioloba)*, blue- or sugar gum (*Eucalyptus cladocalyx*), pine (*Pinus patula*) and vine stumps (*Vitis vinifera*). All are widely available in the Western Cape and commonly sold at the roadside or in shops.

The density, ash content and elemental composition were determined and related to the calorific value. We showed that the wood with the highest calorific value was not necessarily the best option for the braai, if environmental factors are also taken into account.

The calorific value of wood can be related to its chemical composition and varies between 17 – 20 MJ/kg for oven-dry wood. Major elements contributing to the calorific value are carbon, hydrogen and oxygen, whereas nitrogen and some inorganic components contribute to toxic waste gases. Elemental analysis can be used to determine the amount of those components in biomass fuels and to estimate their expected impact on the environment. The typical elemental composition of wood is approximately 51% carbon, 40% oxygen, 6% hydrogen, 0.2% nitrogen and inorganic components that will remain as ash (typically < 1%).

Good braai-wood should ideally have a high carbon content and a high density, since this implies a high energy content and a slow burning process – or in other words, hot and slow-burning coals. Ideally the ash content should be low, so that as much of the available wood is burnt and

Popular braai woods.

converted into energy as possible.

During the burning process, many toxic waste gases are emitted. These range from carbon monoxide (CO) to nitrogen oxides (NOx), which contribute to the greenhouse effect, leading to acid rain and negatively affecting human health. In this study the nitrogen content of the wood species was determined and regarded as an indicator of the degree to which toxic components are formed during combustion.

Apart from the nitrogen content, the presence of metals and other trace elements in the wood samples was determined. Heavy metals such as aluminium, lead, cadmium and arsenic are toxic to humans and the environment.

Density and calorific values of the evaluated fuelwood species

We looked at the different available firewood types in terms of energy content and environmental impact. We developed a simple credit system for choosing wood by looking at the density, ash content, calorific value and the elemental composition of all the examined wood types.

The calorific value of the five evaluated wood species ranged from 18.68 – 19.03 MJ/kg.

Density and calorific value

Wood species	Average density (kg/m^3)	Average calorific value (MJ/kg)
Rooikrans	800.72	18.99
Camelthorn	963.13	19.03
Bluegum	744.62	18.87
Pine	440.00	18.68
Vine stumps	597.37	18.73

As expected, a higher density relates directly to a higher calorific value. Camelthorn had the highest density and also the highest calorific value, while pine showed the lowest density and calorific value.

Ash, carbon and nitrogen content of the evaluated fuelwood species

Vine stumps had the lowest ash content, followed by pine, rooikrans, bluegum and camelthorn. Generally the hardwood species show a higher ash content than the softwoods and vines. The difference in ash content is statistically more significant than the difference in calorific values, which means that the wood with the highest calorific value is not necessarily the best option as firewood. If ash content and calorific value are taken into account, the best option would be rooikrans.

Bluegum has the lowest nitrogen content, followed by pine, camelthorn, rooikrans and vine stumps. The higher the nitrogen content, the more likely is the formation of toxic nitrogen oxides and nitric acid, which have a negative impact on the environment. If calorific value, ash content and nitrogen content are taken into account, bluegum and pine should be the preferred species.

Concentration of metals and other trace elements (in ppm)

Element	Rooikrans	Camelthorn	Bluegum	Pine	Vine stumps
Aluminium (Al)	20.50	47.50	68.70	348.78	105.90
Arsenic (As)	0.09	0.13	0.07	0.10	0.09
Cadmium (Cd)	0.16	0.06	0.06	0.14	0.17
Lead (Pb)	12.43	25.80	41.53	24.04	142.14

Rating of braai-wood with respect to the determined properties

Species/ Property	Rooikrans	Camelthorn	Bluegum	Pine	Vine stumps
Density	2	1	3	5	4
Calorific value	2	1	3	5	4
Carbon content	2	1	3	3	5
Nitrogen content	4	3	1	2	5
Ash content	3	5	4	2	1
Al content	1	2	3	5	4
As content	2	5	1	4	2
Cd content	4	1	1	3	5
Ld content	1	3	4	2	5
Rating (Sum / 9)	**2.33**	**2.44**	**2.56**	**3.44**	**3.89**

Elemental composition

Wood species	Ash content (%)	Carbon content (%)	Nitrogen content (%)
Rooikrans	2.15	44.78	0.34
Camel-thorn	2.79	46.50	0.30
Bluegum	2.38	44.18	0.18
Pine	0.45	44.20	0.24
Vine stumps	0.34	43.70	0.51

Metals and other trace elements

The concentration of heavy metals and other trace elements present in the braai-wood differed significantly between the species. Pine had by far the largest aluminium concentration, followed by vine stumps, bluegum, camelthorn and rooikrans. The highest lead concentration could be found in vine stumps, followed by blue gum, camelthorn, pine and rooikrans. The large aluminium and lead concentration in pine and vines, respectively, suggests that they might have a negative impact on health and the environment if they are used extensively as fuelwood. The hardwood species on the other hand have a significantly lower content of aluminium and lead and therefore present a better choice of fuelwood.

The cadmium and arsenic levels are below 0.2 ppm for all species. The highest concentrations could be found in vine stumps and camelthorn, respectively.

If all properties are taken into account and the wood species are ordered accordingly from 1 (best) to 5 (worst), we can devise a simple rating system that allows us to compare the species and decide which is the most suitable braai-wood in terms of energy output and environmental impact.

Based on this rating, the preferred braai-wood species should be rooikrans (2.33), followed by camelthorn (2.44), bluegum (2.56), pine (3.44) and lastly vine stumps (3.89).

Bluegum is classified as a Category 2 invasive species and may be commercially used in specific areas. Since it is not as invasive as rooikrans, it would seem possible to cultivate it specifically for firewood. The continued use of invasive rooikrans, which according to our results constitutes the best choice of fuelwood, will help to clear the existing stock of these plants, which present a real problem on farmland in the Western Cape. □

Dr Martina Meincken is a senior lecturer in the Department of Forest and Wood Science at University Stellenbosch.

Rare dragons

Michael Samways and **James Pryke** tell us the good news about the return of rare dragonfly and damselfly fauna to the Western Cape.

Top (left and right): The very rare and red-listed mahogany presba dragonfly, which returned to Table Mountain after an absence of over 30 years once foreign invasive pines had been removed. Image: Courtesy of Michael Samways

Above (middle): Disa stream on top of Table Mountain was virtually 'killed' by foreign pine trees shading out the habitats of very rare and unusual dragonflies and damselflies. Stumps of the old pines can be seen in among the rapidly recovering fynbos. Image: Courtesy of Michael Samways

Above: The conspicuous malachite is among a group of very localised damselflies confined to southern Africa. This particular damselfly only occurs in the Western Cape and is being threatened by invasive foreign trees. When the trees are removed this damselfly recovers, as on top of Table Mountain.

Image: Courtesy of Michael Samways

The Cape Floristic Region is famous for its dragonflies as much as it is for its plants. There are many rare species, many of which are unique to the region, making it a special destination for dragonfly enthusiasts from around the world.

This dragonfly fauna has been under major pressure for many years as a result of increasing invasion by foreign trees into the water systems of the area. These trees have established and spread along the waterways, shading out native bushes and so the dragonfly and damselfly habitats. The native bushes are needed by species such as the delicate damselflies as egg-laying sites. Without them they cannot complete their life cycles. Most species also need sunny conditions along the rivers where they hunt smaller insects,

and damsels return

such as gnats. When conditions are too shady the dragonflies and damselflies don't fly and their prey also disappears. This inevitably leads to loss of these species.

The ground under these invasive species is almost devoid of native flowers and wildlife. This is a particularly serious situation in the Cape, where many species are endemic to the region. When they are lost from the Cape, they are lost from the world.

Removing the foreign trees restores biodiversity and also improves other aspects of the natural environment, such as restoring the normal hydrological processes. Ethically, returning this part of the Cape to its natural state prevents what is called 'the extinction of experience' – a homogenised world, where diversity of life and of experience is being lost.

Return to the wild

Several streams in the Cape have seen a significant recovery of the native dragonflies and damselflies. Two of these species, the Ceres streamjack (*Metacnemis angusta*) and the mauve bluet (*Proischnura polychromatica*), were thought to be extinct; the streamjack had not been seen for over 80 years. They returned as the foreign trees were removed; no-one knows where they were living previously, but they were able to recolonise as soon as their normal environment was restored. This recolonisation occured in the Franschhoek area, an extreme case of very good conservation news across the province.

Disa Stream, on top of Table Mountain, shows one of the most dramatic recoveries, illustrated using a specially designed index. This stream, just above Hely-Hutchinson dam, used to be shrouded by pine trees, which are still present as huge but gradually rotting tree stumps, and was effectively 'dead'. Today, after just a few years, it has shown an amazing recovery. The dragonflies and damselflies that have returned include the mahogany presba (*Syncordulia venator*), the conspicuous malachite (*Chlorolestes conspicuus*), the Palmiet sprite (*Pseudagrion furcigerum*) and the friendly hawker (*Anax minuscula)*, all South African endemics. The first three are endemic only to this corner of the South-western Cape. The mahogany presba had not been seen in the area since the 1970s. What is interesting is that the populations of these species are strong and, important for their genetic diversity, which allows them to weather adverse conditions.

This study of Table Mountain has clearly shown that the identification of a key threat, in this case invasive alien trees, and a concerted management approach, removing these trees, can lead to excellent recovery of the local fauna.

Above: The male of the Palmiet sprite damselfly, confined to pristine streams in the Western Cape. It is unusual for a male damselfly to be so brightly coloured and to live such an exposed life on the surface of stones midstream. This species was pushed out of Disa stream, Table Mountain, by the foreign pine trees, but has returned now that the pines have been removed. Image: Courtesy of Michael Samways

The future

It is now essential to keep a watchful eye on Disa stream, as well as other important sites, to prevent the return of invasive aliens. Interestingly, while these environments are delicate, the species that inhabit them are resilient once corrective action is taken. This conservation success story will provide future generations with a distinctive Western Cape environmental experience. □

Michael Samways is Professor of Conservation Ecology and Entomology at the University of Stellenbosch. His special research interest is invertebrate conservation ecology.

James Pryke is a research associate in the Department of Entomology at the University of Stellenbosch. His special interest is ecological networks.

Unlocking the secrets of the sea:

The research vessel Dr Fridtjof Nansen.

A three-month voyage on the Norwegian research ship, ***Dr Fridtjof Nansen***, provided South African biologists and oceanographers with an opportunity to conduct pioneering oceanographic research in the western Indian Ocean. In this, the first of two articles on the recent voyage of the *Dr Fridtjof Nansen*, **Claire Attwood** and **Denis Tweddle** look at the fish research that was conducted on the Mascarene Plateau, a remote chain of islands, banks and shoals situated to the northeast of Madagascar.

The *Dr Fridtjof Nansen* is named after the Norwegian explorer and philanthropist who, in the late 1800s, made important discoveries in several aspects of modern marine research, particularly physical oceanography – the study of currents and the physical properties of ocean waters.

The research ship is one of the most advanced in the world. Between August and December 2008, the *Dr Fridtjof Nansen* provided a platform for 83 scientists from 27 research institutions to conduct intensive oceanographic surveys in the western Indian Ocean. Among the scientists working on the *Dr Fridtjof Nansen* during this period were 33 South Africans. A further 24 scientists from other African countries, including Madagascar, Mauritius, Seychelles and Mozambique, participated in the voyage.

Surveys began off Madagascar where, for the first time in history, the full extent of the East Madagascar Current was surveyed. They continued off Mauritius, where the deep-sea environment of the tropical island and its possessions was investigated. Then two teams of oceanographers and biologists conducted a comprehensive survey of the Mascarene Plateau. Finally, scientists on board the *Dr Fridtjof Nansen* tracked the movement of dipole eddies – massive swirls of water that move through the Mozambique channel.

According to Johann Lutjeharms, Professor of Oceanography at the University of Cape Town, the 2008 voyage of the *Dr Fridtjof Nansen* resulted in 'a huge jump' in multidisciplinary understanding of the marine ecosystems of the western Indian Ocean.

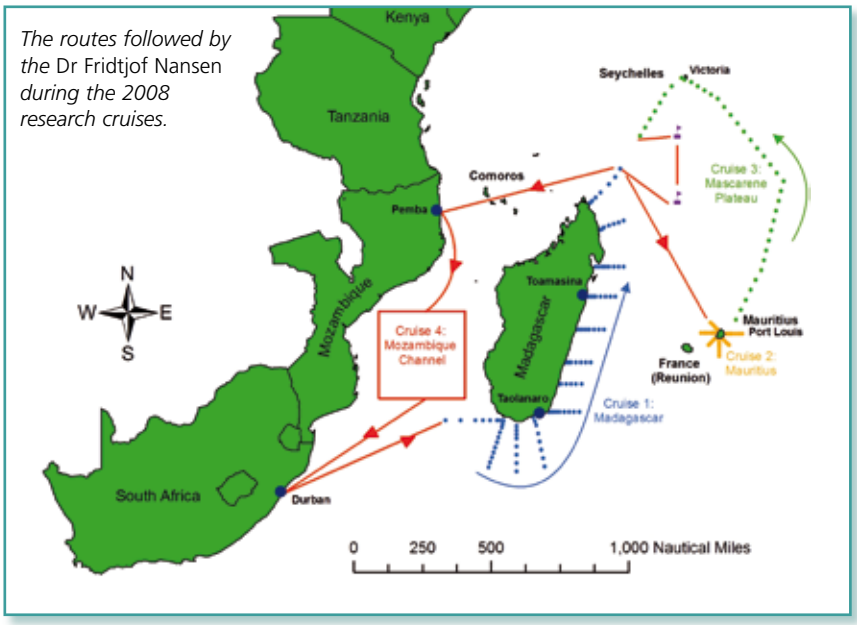
Dr Fridtjof Nansen

The research vessel *Dr Fridtjof Nansen* is owned by the Norwegian Directorate for Foreign Aid (NORAD) and staffed by the Norwegian Institute of Marine Research (IMR). It is a large, sophisticated vessel that currently operates on the west and east coasts of Africa, helping developing countries to carry out fisheries and oceanographic research.

The *Dr Fridtjof Nansen* carries the latest acoustic instrumentation, including a Simrad ER60 echo sounder, which is used to transmit sound waves vertically through the water column and receive their echoes. Since different types of fish reflect sound waves in a characteristic way, the echo sounder allows scientists on board the *Dr Fridtjof Nansen* to estimate the abundance of plankton and various types of fishes while the vessel is underway.

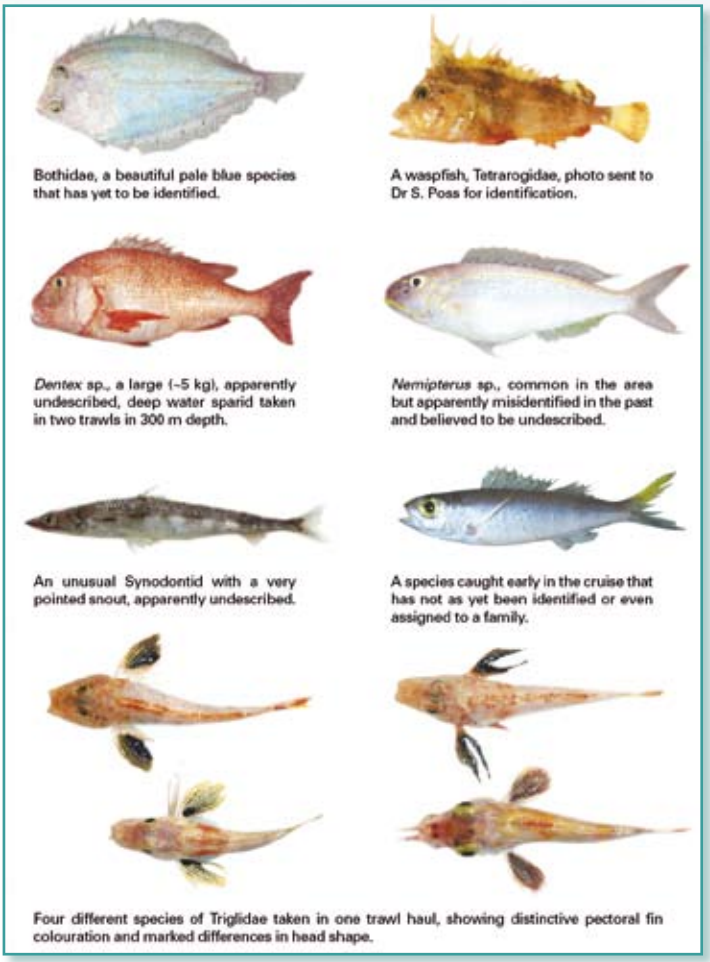
The ship also carries standard sampling equipment such as a CTD, which collects water samples at different depths and measures depth, salinity, temperature and fluorescence in seawater. A fluorometer measures fluorescence, giving an indication of the chlorophyll content of seawater, while plankton is sampled with a range of nets.

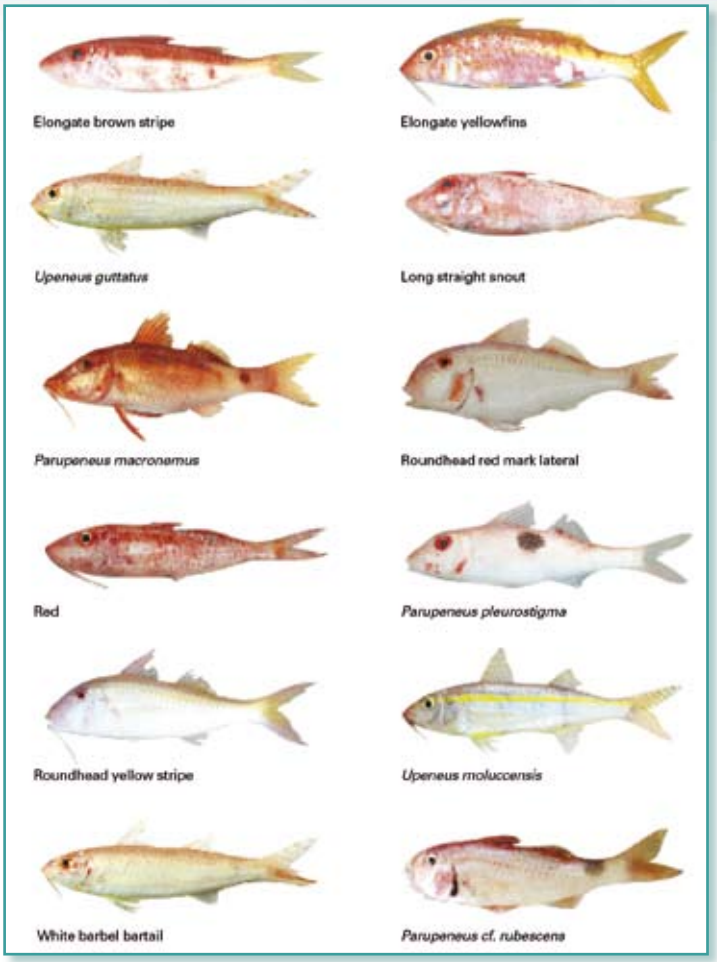
Since 2006, the *Dr Fridtjof Nansen* has been operated by the United Nations' Food and Agriculture Organization (FAO) through its Ecosystem Approach to Fisheries (EAF-Nansen) project. By improving the quality of marine research that is conducted in African waters, the EAF-Nansen project seeks to provide fisheries research and management administrations with knowledge about their marine ecosystems, so that they can better monitor and manage them.



The routes followed by the Dr Fridtjof Nansen *during the 2008 research cruises.*

new fish species in the Indian Ocean





Above left: Plate 1: A selection of species that are yet to be identified, including some that are undoubtably not described.

Above: Plate 2: Different species of the family Mullidae caught during the survey, several with temporary names while awaiting identification.

'This is fundamental, pioneering research that you can't do anywhere else in the world,' said Professor Lutjeharms.

'It is vital for the countries of the region because you can't manage an ecosystem unless you have a basic idea of what the currents are doing and the effects they have on biota.'

Improving the management of marine ecosystems is the ultimate goal of the scientific research that was conducted from the *Dr Fridtjof Nansen* in 2008. Nine countries – Comoros, Kenya, Madagascar, Mauritius, Mozambique, Seychelles, Somalia, South Africa and Tanzania – are working together to gather information about the physical, chemical and biological characteristics of their shared ecosystems, with the long-term goal of better managing them. Their efforts are being supported by the United Nations' Global Environment Facility (GEF), which is funding the five year Agulhas and Somali Current Large Marine Ecosystems (ASCLME) Project.

Based in Grahamstown at the world-renowned South African Institute for Aquatic Biodiversity (SAIAB), the ASCLME Project is helping the nine participating countries to document the environmental problems – such as marine pollution and over-fishing – that are faced by the region. The project's goal is to develop a strategic action programme, or a roadmap, to tackle these problems.

'Scientific findings will lay the groundwork for the countries to develop a strategy for collectively managing the resources on which their people and economies depend,' explained David Vousden, director of the ASCLME Project.

'The 2008 research voyage of the *Dr Fridtjof Nansen* and those that will follow in 2009 and 2010, are integral to achieving the aims of the project.'

Operating a modern research ship like the *Dr Fridtjof Nansen* is extremely expensive and logistically very demanding. The 2008 voyage of the *Dr Fridtjof Nansen* was made possible by a partnership between the ASCLME Project and the Food and Agriculture Organisation (FAO) through its Ecosystem Approach to Fisheries (EAF-Nansen) Project. The collaboration between the two projects will continue in 2009 and a new partnership with SAIAB's flagship African Coelacanth Ecosystem Programme (ACEP) will extend the research effort into South African waters. A survey of the Natal Bight, north of Durban, and the inshore edge of the Agulhas Current are planned and will take place from the South African research ship, *FRS Algoa*.

A highlight of the planned 2009 voyage of the *Dr Fridtjof Nansen* is a 41-day cruise to be carried out on the seamounts of the southern Indian Ocean. ▹▹

Plate 3: A random selection of the fish caught during the Mascarene Plateau survey.

The Barcode of Life

A tiny sample was taken from every fish species that was caught and identified on the *Dr Fridtjof Nansen*. The samples will contribute to the Fish Barcode of Life (FishBOL) initiative, the ultimate aim of which is to make accurate identifications of fish species much easier.

The idea is that when technology moves forward, you'll be able to buy genetic 'barcode scanners' and with a small piece of tissue, get a readout on the species you're dealing with in a few moments, without recourse to keys or even taxonomic experts.

FishBOL is creating a valuable electronic database that contains DNA barcodes, photographs and information on species distributions. It complements and enhances other resources, including FishBase, a global database that contains information about practically all fish species known to science.

For more info: **www.fishbol.org**

Seamounts, or undersea mountains, are known to be hotspots of biological diversity. They also host commercially important species of fish, like tuna and orange roughy. Although seamounts in temperate regions have been visited by scientists, those in more remote regions, like the southern Indian Ocean, are largely unexplored.

The partnership between the ASCLME Project and the FAO and the support of the International Union for the Conservation of Nature (IUCN) will make it possible for scientists to investigate five seamounts in the southern Indian Ocean later this year, ensuring that pioneering science continues aboard the *Dr Fridtjof Nansen*. South African biologists and oceanographers are ideally placed to participate in her 'voyages of discovery' which have the potential to reveal exciting new discoveries about the oceans that surround us.

Reference specimens and type series

A reference specimen is a specimen that is collected and its characteristics recorded in minute detail. The specimen is then used to help in the classification of other species believed to be either the same or similar.

A type series for a species is a collection of the specimens that are used as type species for a genus. The description of the genus is usually based on a type species, that is then modified or expanded by the features of other species that are included in the genus.

Unlocking the secrets of the Mascarene Plateau

The Mascarene Plateau is a submerged volcanic plateau extending over 2 200 kilometres from the Seychelles Bank at 4°S to Mauritius at 20°S. It is a crescent-shaped series of tiny islands and coral-topped banks separated by deep channels. On either side of the banks, steep slopes plunge to abyssal depths of 4 000 m.

Owing its remote location, there have been very limited fish surveys conducted on the Mascarene Plateau in the past and on the *Nansen's* survey of the area, researchers ensured that all fish species caught during the survey were identified as far as possible.

Representative samples of all species were preserved, most with their fins pinned out to ensure that specimens were in good condition for taxonomic study. All fish species were photographed while very fresh to capture perfect colour detail. The photographs will be used to prepare illustrations for a book entitled *Fishes of the Western Indian Ocean*, which is being written and illustrated by well-known South African fish taxonomists, Phil and Elaine Heemstra.

The collection of reference specimens for all species collected, and type series for species believed to be undescribed or poorly represented in earlier collections, resulted in a provisional total of 271 fish species in over 80 families. Most species were positively identified on board the *Dr Fridtjof Nansen* using available reference materials, including FishBase on-line, *Smith's Sea Fishes*, Heemstra & Heemstra's *Coastal Fishes of Southern Africa*, FAO identification guides for the western Indian Ocean, FAO species catalogues for various important families, Compagno *et al.*'s field guide to the sharks of the world and the South African guide to sharks and rays, and also various field guides to coral reef fishes in the Indian Ocean.

Phil and Elaine Heemstra were in regular e-mail contact with the scientific crew on the *Dr Fridtjof Nansen* and helped to positively identify many specimens. When they were unable to identify a specimen, photographs were sent to experts in Japan, Australia, France, Norway and the USA to get their opinions.

Some examples of the kind of fish research that was conducted on the *Dr Fridtjof Nansen* are presented in the three illustrations, called plates. The first, plate 1, presents a selection of species that are either undescribed or are poorly represented in the literature of the fishes of this area.

Plate 2 is an example of the photographs taken of all species of one family, in this case the Mullidae (goatfishes), presented together to make identification easier.

Plate 3 includes photos of a random selection of species that indicate the quality of photos available for use in the preparation of illustrations for the forthcoming *Fishes of the Western Indian Ocean*.

Specimens collected on the Mascarene Plateau have been delivered to SAIAB and work is continuing on their classification. Once identified and preserved, the specimens will be added to SAIAB's fish collection which consists of at least 650 000 individual fish specimens from southern Africa, its surrounding oceans and elsewhere in the world.

Large drums of fishes are methodically being emptied as the process of identifying and preserving the specimens takes place. It is anticipated that by mid-year the specimens will all have been described and work will have begun on publishing an illustrated checklist of the species caught during the survey, including descriptions of species that are confirmed as new by taxonomic experts.

Muscle tissue samples were also collected from all species. They will be analysed through the Fish Barcode of Life (fishBOL) initiative and also used for other genetic studies as and when these are conducted.

Biodiversity assessment

Trawling the seabed for scientific specimens is no simple matter and, while every effort was made to explore

all depths down to 300 m, this proved difficult in many areas. In shallow water, extensive corals fouled trawl gear and in other areas, very steep slopes stretched the capabilities of the research ship and her experienced crew.

Catches were very variable. The most noteworthy catches came from the last three hauls of the survey, which yielded catch rates between 484 and 819 kg/h[1] and it appears that the northern part of the survey area is more productive than the areas to the south. The highest species diversity was recorded in the last two trawls of the survey, with 60 and 64 fish species listed. This was remarkable given that the first four trawls on the Seychelles bank at similar depths yielded only 13 to 28 species, while no other trawls during the survey yielded 40 species or more.

Although some idea has been obtained of the distribution and abundance of more common species in the Mascarene area, the survey must be regarded as providing a preliminary impression of the diversity and abundance of the fishes in the area. The data will be compared with the species list produced in 1978 after a trawl survey was conducted in the area, also by the *Dr Fridtjof Nansen*.

In addition to the demersal (seabed) trawls, six pelagic trawls were conducted at night to investigate the composition of concentrations of organisms revealed in an acoustic survey. The *Dr Fridtjof Nansen* is equipped with state-of-the-art acoustic equipment that allows scientists to estimate the abundance of plankton and various types of fish species while the vessel is underway. Trawling is a way of verifying the information gathered in the acoustic survey.

Four trawls were deployed in midwater at various depths, while two trawls were carried out in the surface layer. The pelagic trawl catches were investigated and samples collected of the various species in the catch. Crustaceans and squid were also recorded. The final species list is uncertain because of a number of informal names used in early trawls that may result in duplication, while close study of the pelagic fauna will undoubtedly increase the number of species, particularly the difficult-to distinguish lantern fishes, in the catch. □

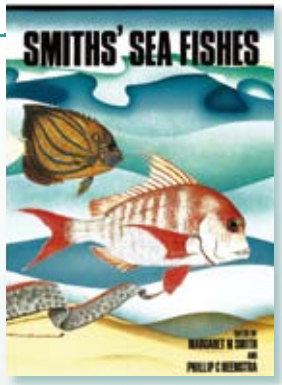
Claire Attwood is a freelance journalist who works as a public relations consultant to the ASCLME Project.

Denis Tweddle is an Honorary Research Associate at the South African Institute for Aquatic Biodiversity. He is involved in numerous, varied fishy projects including a three-year stint coordinating a fisheries research programme on Lake Victoria. In the last year, apart from the six-week cruise on the Nansen, he has conducted EIAs in Tanzania (hydroelectric dam construction) and the Western Cape (invasive alien fish eradication), a fisheries project evaluation on the Zambezi in Namibia, exploration of the fish fauna of the Kwango tributary of the Congo that forms the border between Angola and the DRC, and joined an IUCN workshop in Cairo to amalgamate African red data list regional fish assessments into an overall African assessment.

A selection of specimens obtained from a single trawl.

Fishes of the Western Indian Ocean – a long time in the making

Wouter Holleman describes how this book came into being



JLB Smith was a chemist as long ago as 1923, when he was appointed as senior lecturer in the Department of Chemistry at then Rhodes University College. He had just returned from the University of Cambridge with a PhD.

One of JLB Smith's pastimes was organising fishing holidays for selected students, travelling by train and ox wagon. It was during these years that he developed a keen interest in ichthyology, specifically in which kinds of fishes were found in South African waters.

Less than 10 years later, in 1931, his first paper in ichthyology was published by the Albany Museum in Grahamstown: 'New and little known fishes from the east coasts of Africa.' And, as some would say, 'the rest is history'.

There are two important bits of this history pertinent to our story. The first is that in 1946 the South African Council for Scientific and Industrial Research was established and awarded JLB Smith a Research Fellowship for three years to pursue his research into fishes. Rhodes University provided him with accommodation and equipment and appointed him research professor in the Department of Ichthyology.

The second bit of history is that three years later, in 1949, the first edition of the *Sea Fishes of Southern Africa* was published. The fifth edition was published in 1965. JLB died in January 1968.

Then came a long hiatus, until Phil Heemstra joined the staff of what had become the JLB Smith Institute of Ichthyology, in 1978. He and Margaret Smith, JLB's widow and director of the Institute, soon started work on a new version of the old *Sea Fishes* book. Their labours, and those of a whole swathe of collaborators, culminated in the publication of *Smiths' Sea Fishes* in 1986.

Smiths' Sea Fishes too went through several editions and printings, and is now not only out of print, but out of date. However, the realisation that 'something had to be done' came only about six years after the book was first published. Our knowledge of fishes grows almost on a daily basis. In fact, an average of 30 new species of fishes have been described each year for the past 20 years! In the Western Indian Ocean nearly 50 new species have been described in the past five years.

In 1995, Phil Heemstra went into 'partnership' with Jack Randall of the Bishop Museum in Hawaii. Their aim was somewhat more ambitious than another *Smiths' Sea Fishes*. It was to make a record of all the coastal fishes of the western Indian Ocean, in as much as that is possible. Heemstra and Randall also enlisted the help of 50 other specialists on various fish groups. And, most importantly, they brought on board Elaine Heemstra, *artiste extraordinare*, who is illustrating the various species, both in colour and as ink drawings.

Between starting on this huge project and now, Phil and Elaine also took about three years to write and illustrate the popular *Coastal Fishes of Southern Africa*, which was published in 2004.

Because of the larger geographic area being covered – from Cape Point to the Gulf of Aqaba, and as far east as Sri Lanka – the book will consist of two volumes. The Institute (now the South African Institute for Aquatic Biodiversity (SAIAB)) is planning to publish it in 2010. More than half of the 240 chapters have been submitted. Each chapter deals with a family of fishes; some of them are short as there is only a single species in the western Indian Ocean, and some are very substantial, dealing with 80 or more species. And there are more than 300 species of gobies! Elaine has completed about 80 of the colour plates, illustrating some 1 200 species.

Where does your fish come from?

When you look at a menu in a restaurant you probably assume that the fish species listed are correctly identified. But it would seem that you may be wrong in many cases.

A recent survey of fish, in restaurants and from wholesale agents, by Dr Sophie von der Heyden of the University of Stellenbosch in conjunction with WWF's Sustainable Seafood Initiative, showed that around 50% of the fish that you are eating is mislabelled. She looked at 178 samples, using fish fillets, because these are generally unrecognisable anyway. She concentrated on dorado (*Coryphaena hippurus*), yellowtail (*Seriola lalandi*), kingklip (*Genypterus capensis*) and cob (*Argyrosomus* spp.)

She found that 80% of fish labelled as cob was something else. It was usually either big scale mackerel (*Gasterochisma melampus*), croaker (Family: *Sciaenidae*) or warehou (*Seriollela* spp.). The mackerel and croaker are found in temperate waters worldwide, while warehou is endemic to southern Australia.

Of the kingklip sampled, all the specimens were actually kingklip, but 30% were from New Zealand and not from local waters. Sophie was able to determine this by using genetic markers that showed that the species were from a different population.

Sophie used a technique called PCR (polymerase chain reaction) to identify the fish species. By using gene-specific primers, she was able to amplify a gene used for the genetic identification (or barcoding) of fishes. PCR is a very straightforward technique – it amplifies millions of gene copies from only a few copies that are present in DNA. Using a process called sequencing, you can read the genetic composition of a particular fish fillet, i.e. the sequences of the di-nucleotides that can distinguish between species, populations and even individuals! This gene is then compared to a global database called GenBank, which contains gene sequence information for everything from microbes to humans, as well as fishes. The database scans through all data available in it, and reveals the closest matches to the gene sequence submitted to it. This is quick and easy to do, and you can usually identify the true identity of a particular fillet with 98–100% confidence!

You may not think that it is all that important to know the exact identity of the fish that you are eating. But this mislabelling has several implications. The first is the expense. Fish are expensive and some are more expensive than others. If you are paying for what you think is cob and you are getting an inferior fish, then you are being cheated.

(See **www.wwfsassi.co.za** to find out how you can make sure the fish you are eating is not endangered.)

Dorado is also called mahi-mahi. This one was caught in Mauritius.

Image: Wikimedia commons

Mislabelling also undermies consumer campaigns about fish choice. Fish stocks are suffering from over-exploitation in most parts of the world and it is possible to make 'green' choices about what you want to eat in order to promote sustainable fishing. If your fish is being mislabelled you cannot do that.

There are also potential health risks with, for example mackerel being labelled as cob. An example is ciguatera poisoning, which is a food-borne illness in humans caused by eating fish whose flesh is contaminated with the toxin ciguatoxin. This occurs in makerel species, but is not found in cob.

And then there is the question of sustainable fisheries. If wholesalers are selling fish that is endangered and labelling it as something else, then it becomes very difficult for governments to control the industry, something that is becoming increasingly important as fish stocks around the world decline.

Fact File

Wrasses of the Indian Ocean

All the fish species illustrated in these beautiful plates are wrasses. They belong to the family Labridae, which is a very large family that contains about 500 species. The family is abundant on and highly characteristic of coral reefs, although some species live entirely in temperate waters. There are more than 130 species in western Indian Ocean waters.

Wrasses are mostly carnivores and eat a variety of small invertebrates. They are also diurnal and are among the first species to retire into nooks and crannies at dusk to sleep. Many of the smaller species bury themselves in sand for the night.

Although most species grow to 10–20 cm in length, many are much larger and grow to 40–50 cm. The smallest, *Pseudochelinops ataenia*, is only 5 cm in length and the largest, the humphead wrasse, *Cheilinus undulatus*, grow to more than 2.2 m and can reach 25 years old. The males of this species can weigh as much as 190 kg. Females are much smaller.

Wrasses are curious because they swim with their pectoral fins rather than with their tails, as nearly all other fish do. The pectoral fins move in a rowing motion. This can give them the appearance of birds flying over the reefs.

Like many other marine fishes, many wrasses change sex as they grow. The start as a female and then become male. They also often change colour as they become larger, as can be seen in the pairs in the illustrations. These are called the 'initial phase' colour and the 'terminal phase' colour. The terminal phase males are often much gaudier than the females.

Above left (clockwise from upper left:) Cheilinus trilobatus *(adult – tripletail wrasse);* Cheilinus undulates *(adult – giant humphead wrasse); same (juvenile);* Cheilinus arenatus*; tripletail juvenile. Left (left from top to bottom):* Cheilinus chlorurus *(adult – floral wrasse); same – juvenile;* Oxycheilinus mentalis. *Right top to bottom:* Oxycheilinus bimaculatus *(two-spot wrasse);* Oxycheilinus digramma *(cheeklined wrasse, two colour forms)*

Images: Plates courtesy of the South African Institute for Aquatic Biodiversity

Blue crane (Anthropoides paradisea) *pair.*
Image: Wicus Leeuwner

Citizen science flourishes at the Animal Demography Unit

Have you ever wished you could be a research scientist helping to conserve our wildlife, but you don't have a formal degree or any scientific training? At the University of Cape Town's Animal Demography Unit (ADU; www.adu.org.za) there is a menagerie of projects to choose from, providing citizen scientists (or volunteers) the opportunity to get outdoors and collect valuable data for science and conservation. It's easy to become involved and it's a lot of fun.

The ADU is a leader in atlas projects in South Africa. It all began 21 years ago when fieldwork started for the first Southern African Bird Atlas Project (SABAP1). It ran for five years, ending in 1992 and produced the first comprehensive atlas of bird distribution for southern Africa. Thousands of citizen scientists enthusiastically provided over 100 000 checklists for SABAP1. The maps produced have subsequently been used in recent bird field guides and in the seventh edition of *Roberts' Birds of Southern Africa*. Bird distribution has changed in the last two decades, but by how much and what are the implications for bird biodiversity conservation? SABAP1 proved to be so popular, that SABAP2 was launched to help answer these questions. SABAP2 (http://sabap2.adu.org.za) was launched on 1 July 2007 and plans to run until 2011, covering South Africa, Lesotho and Swaziland. It is funded by the South African National Biodiversity Institute (SANBI), with the ADU the main implementing agency. BirdLife South Africa is coordinating the training and public outreach component of the project. SABAP2 has been refined to collect more detailed information on bird distributions, and submission of data is mainly electronic. Data and coverage maps are reflected and updated on the project website every three hours. The project requires some level of bird identification but novice birders can also get involved by attending training sessions and bird ID courses which are run by regional bird clubs. The project also has Regional Atlas Committees which assist in promoting the project and getting prospective atlasers up and running. Currently there are 462 active registered atlasers.

For more information on SABAP details on the protocols, and how to register as an atlaser, please visit **www.sabap2.org** or contact Doug Harebottle (doug.harebottle@uct.ac.za, tel 021 650 2330) or Les Underhill (les.underhill@uct.ac.za, tel 021 650 3227). ▷▷

*Above left: Painted lady (*Vanessa cardui*).* Image: Jenny Norman

*Above right: Citrus swallowtail (*Papilio demodocus demodocus*).* Image: Jenny Norman

Left: Volunteers Themba, Marlei and Sarah get up close and personal with Cape cobras on SARCA field trip 8. Image: Marius Burger

Left bellow: Learners of Rusthof High School discover a Parrot-beaked Tortoise at Harmony Flats Nature Reserve, as part of a SARCA survey. Image: Marienne de Villiers

After SABAP1, atlassing was well established within the ADU, and so the Southern African Frog Atlas Project (SAFAP) was launched in 1995. This project was completed in 2003 and a Frog Red Data Book and Atlas was published soon thereafter. 420 citizen scientists submitted data towards SAFAP. Frogs naturally led on to reptiles.

Nile crocodiles, puff adders and Cape cobras – all creatures that strike fear into the hearts of many South Africans. But these are just a few of a fascinating group of animals that can be described as 'mostly harmless'.

The Southern African Reptile Conservation Assessment (SARCA) was launched in 2005 and ended in March 2009. The reptile biodiversity of South Africa and its neighbours, Lesotho and Swaziland, is astonishing; it comprises about 410 types of reptiles, with new types discovered every year. Yet basic information about these creatures – distribution, conservation status and threats – is hard to come by. This is a situation that SARCA aims to rectify. SARCA is a partnership between the ADU and the SANBI. Twenty experts have freely given of their time and knowledge to compile up-to-date assessments, according to IUCN standards, of the status of the region's reptiles. This information will be compiled into a long-overdue new red data book, due to be published by SANBI in 2009. The last such publication on reptiles appeared twenty years ago! The new publication will not only be a reptile red data book but also an Atlas. Since 2005, SARCA has collected reptile distribution data from museums, literature sources, members of the public (via the innovative online Virtual Museum for the submission of reptile photos – http://sarca.adu.org.za) and through the project's own field trips. The Virtual Museum has received 6 000+ photographic records submitted by 350 citizen scientists. The atlas will, for the first time, bring all of these records into a single publication, with maps illustrating where in the region which reptiles occur.

By now the atlas bug was well established within the ADU, and a bug atlas was decided on. Consequently, the Southern African Butterfly Conservation Assessment (SABCA) was launched in April 2007, ending in 2011. SABCA has similar aims to SARCA, and will also produce an updated butterfly red data book and atlas. It is a partnership between the ADU (project management), SANBI (funding) and the Lepidopterists' Society of Africa (LepSoc; funding and expertise). There are close to 700 species of butterflies in the atlas region, of which about 40 are threatened with extinction and two are already extinct.

To get a better understanding of South Africa's butterfly biodiversity and conservation priorities, SABCA is basing its conservation assessments

*Above: A purple heron (*Ardea purpurea*), one of many waterbirds to be seen during a CWAC count.* Image: André du Toit

on data from museum and private collections, field surveys and an online virtual museum which was launched due to the popularity of SARCA's online Virtual Museum. Over 100 citizen scientists have submitted photos to the virtual museum, and 5 000+ photographic records have been received – a great achievement in a short space of time. LepSoc members are voluntarily giving up much of their free time to conduct the field surveys, assist with the ID of butterfly photos and to conduct the conservation assessments for all our butterfly species. More information on how to become part of the butterfly net can be obtained on SABCA's website: http://sabca.adu.org.za

The ADU was originally known as the Avian Demography Unit, and runs other non-atlas type bird projects which cater for citizen scientist involvement. SAFRING is based at the ADU and provides bird ringing services in South Africa and other African countries. This entails providing ringing equipment to qualified ringers, and curating all ringing data. SAFRING holds national training courses, annually if there is sufficient demand. SAFRING has a strict code of ethics to ensure the safety of birds handled. SAFRING acknowledges the importance of bird ringing in that it has been described as the most important tool in ornithology in the 20th century. SAFRING celebrated its 60th anniversary in 2008. Most bird ringers are amateurs and spend their own time and money to contribute valuable ringing data. Birds with rings that are found by the general public should be reported to SAFRING (email Dieter.Oschadleus@uct.ac.za, tel: 021-650-2421) and a history of the bird will be sent to the ringer and to the reporter. Currently there are about 150 active bird ringers. All citizen scientists can also help by keeping a close watch for colour rings on living birds.

If you'd rather count than ring birds, get into your car and join CAR (Coordinated Avifaunal Roadcounts). Imagine driving 19 000 km along gravel country roads, stopping every 2 km, to count cranes, bustards, storks and other large terrestrial birds within seven provinces on one day! This is only possible due to the combined efforts of over 750 bird-watchers (farmers, bird club members, nature conservationists and some schools) who climb into their cars on the last Saturdays of January and July to count these big birds, along 350 fixed routes, through agricultural areas.

The CAR project, coordinated by the ADU, monitors trends in populations and habitat use of over 30 species, including 15 threatened Red Data species. The project has been running for over ten years in most regions and fifteen years in the Overberg region of the Western Cape, where it began. Most large terrestrial birds have huge ranges and are not adequately conserved within protected areas. These birds are also very important indicators of biodiversity on farms. For more information visit the CAR webpage: http://car.adu.org.za The CAR project is also supported by SANBI, as well as bird clubs and for a fixed period the Darwin Initiative project 15/002 and the Critical Ecosystem Partnership Fund.

How about counting waterbirds at the many wetlands around our country? If you are interested, then the Coordinated Waterbird Counts Project, CWAC for short, is for you! The CWAC project started in 1992 and today, 17 years on, it is still going strong. Currently the project monitors approximately 400 wetlands around the country on a bi-annual basis – once in summer and once in winter. The counts are conducted by citizen scientists, and at the moment we have around 1 600 people from all over the country volunteering their time towards this worthwhile cause. The focus is on waterbirds only, which include mainland and shorebird species, of which there are approximately 140 in South Africa. Wetlands that form part of the project range in shape, size and distribution, can be natural or artificial, permanently wet or seasonal, freshwater or marine. If it supports waterbirds, it can be included in the project! For more information, please feel free to visit the CWAC website at: http://cwac.adu.org.za. The CWAC project is supported by SANBI.

Each data point the ADU's citizen scientists collect is a piece in the jigsaw puzzle of biodiversity. The ADU's mission is to fit together all the puzzle pieces, so that we can map South Africa's biodiversity through time. We turn the myriad bits of raw data into the kind of information that conservation decisions can be based on. As a member of the public, you no longer need to be an 'activist' to contribute to conservation, you can be a citizen scientist, contributing your pieces to the jigsaw. If you're a budding citizen scientist or looking for new projects to join, consider joining the ADU projects, to help us get the bigger picture. □

MODELS OF HOPE: Developing

Catherine Govender gives us some insight into important research being carried out on breast cancer in South Africa.

Top: Annie spends at least ten hours a day planning, monitoring experiments and documenting progress.

Middle and above: One of Sumari's many responsibilities is to make sure that the cell cultures are not contaminated. Contaminated cells put paid to hours (or even days and weeks) of hard work.

Breast cancer. For many women these two words are the embodiment of the many fears we hold – not only our fears about death, but also our fears about who we are and how we are seen by others, including our loved ones [1]. Although breast cancer does not exclusively occur in women, it is the most commonly diagnosed female cancer in both the developed and the developing world. At present, female breast cancer accounts for 20% of the incidence of all cancers in South Africa. In 2007, nearly half a million women around the globe lost their battle with this disease. In the same year, 1.3 million new cases were reported worldwide [2–4].

Radical mastectomy is no longer the only treatment option, and, while survival is increasing all the time, the chemotherapeutic and radiotherapeutic treatments of breast cancer remain works in progress[5]. Chemotherapy is aimed at destroying cancer cells with drugs. Unfortunately, chemotherapy drugs generally cause the death of many healthy cells along with the cancer cells. In the current pursuit of better chemotherapy agents, the emphasis is on developing new drugs or more effective analogues of older pharmaceuticals to limit the impact on quality of life. Imagine chemotherapy without the hair loss… or perhaps without the mouth sores. Thanks to new technology, highly specific, low toxicity chemotherapy drugs may be part of the next generation of treatment for breast cancer.

Leading research institutes are now employing strategies such as advanced computational methods to model analogues for breast cancer treatment. It is at the cutting edge of this field that we find Professor Annie Joubert of the Department of Physiology at the University of Pretoria. As one of the leading researchers in her field of cell death, Annie is perhaps not what one would imagine a staid researcher should be. In fact, when meeting her for the first time, one may be forgiven for thinking that she is a junior in her department: quiet and petite; her gentle nature has led many colleagues to joke about the day she finally says *'No'* when asked a favour. Annie sits on no less than five academic and research committees and administers seven grants. She accomplishes all this while carrying out a full lecture load and supervising her postgraduate students. Annie spends at least ten hours a day planning, monitoring experiments and documenting progress. With a history of breast cancer in her own family, she hopes that scientists be successful in combating the disease.

At present, Annie's cell research laboratory is run by Sumari Marais. Sumari joined the Department of Physiology in 2003 with a BSc in Molecular and Cellular Biology and then did an Honours degree in Biochemistry at Stellenbosch University. Sumari and Annie have worked together for six years. Their cancer research mainly focuses on the exposure of breast adenocarcinoma (MCF-7) and non-tumourigenic epithelial breast (MCF-12A) cells to oestrogen metabolites.

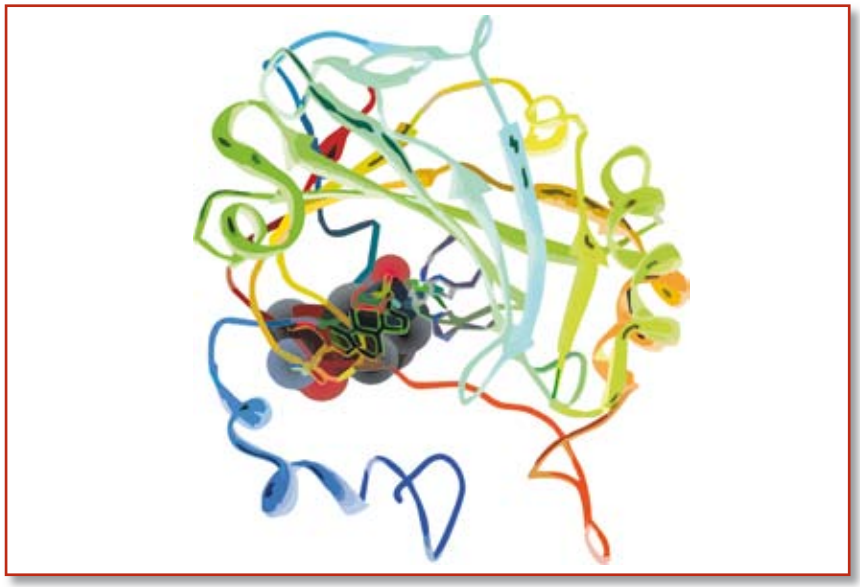
Work in progress

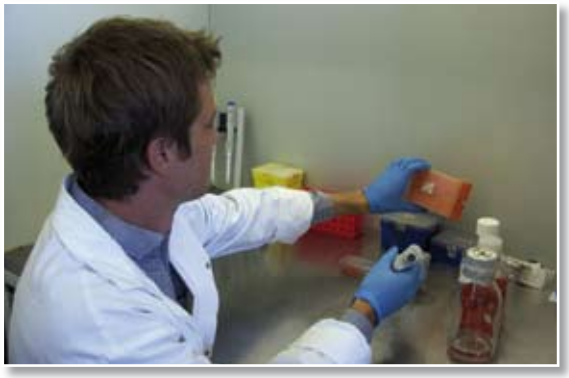
The first metabolite they examined was 2-methoxy-17ß-estradiol (2-ME)[6]. 2-ME exerts anti-mitotic influences – it

Mentoring young scientists

Like any true scientist though, Annie is also intrigued by the new mysteries that unfold with every research step and her greatest challenge is keeping her finger on the incredibly rapid pulse of cellular research. Annie finds her work with postgraduate students most rewarding and feels strongly about being an example to them. This means that she reads as much as she can, publishes frequently and regularly applies for grants. Much of this funding goes towards student development. Annie feels that she has a responsibility to mentor young scientists. She tries to take on board at least two postgraduate students every year. To date she has successfully supervised 15 postgraduate studies. Annie reflects on her role as mentor in her field: *'I want to feel as though I had an impact. I hope that my students will remember me as a person that reached out and touched them – not only on a science level, but as a whole person.'* Someone who had a profound impact on Annie's own career was Professor Johanna Seegers, who in 1998 recruited Annie into the cellular research programme during her PhD studies in Biochemistry at the University of Pretoria. Annie quickly climbed the ranks and was promoted to Associate Professor in 2005.

molecules for fighting breast cancer





Left: 2-Methoxyesteradiol-bis-sulfamate bound to carbonic anhydrase II. Carbonic anhydrase IX and XII are up-regulated in many tumours and play a role in promoting metastasis (distant spread of the cancer). The new analogues bind and inhibit carbonic anhydrases, thereby playing a role in minimising the effects of tumour promoting CA IX and CA XII enzymes and their effect on metastasis. The new analogues are also being designed to bind to the ADP-binding-site of the Kinesin Motor Protein and to tubulin at the colchicine-binding site to halt mitosis.

Above: André spends a great deal of his day in the laboratory charting the progress of the cells treated with the 2-ME and its new analogues. "The worst part of the work is coming to the end of the day and feeling I haven't done enough," says André.

inhibits cell division (mitosis). Cancer cells are distinguished from healthy cells by their rapid uncontrolled multiplication. 2-ME blocks the cell cycle in metaphase. This disruption of the cell cycle induces apoptosis (programmed cell death) in cancer cells. 2-ME also blocks the formation of blood vessels around the cancer cells (the process of angiogenesis). The effect on healthy cells (MCF-12A) is relatively less intense. In other words, 2-ME is less toxic to normal breast cells than it is to the cancer cells. Similar results have been reported by other laboratories and in various types of cancer cells. 6 However, the low oral bioavailability of 2-ME and its fast metabolic degradation need to be addressed. Annie is therefore facilitating the group's efforts in the design, synthesis and *in vitro* evaluation of novel 2-ME analogues as potential anticancer agents. To this end they have partnered with the Department of Chemistry's Professor Robert Vleggaar at the University of Pretoria. The partnership has proven to be a wise investment, with sulfamoylated derivatives being successfully synthesised.

The starting molecule, 2-ME, was modified at various positions *in silico* in order to increase its activity and biological availability. Of the many compounds created, the three most promising were selected for further research. This project is the responsibility of André Stander, one of Annie's PhD students. So far, André has found the three new compounds to be five- to twenty times more biologically active *in vitro*, than the parent compound, 2-ME. There are countless tests that have to be performed to make sure a cancer drug is effective and safe for use. These novel agents are not as yet commercially available and have been synthesised by iThemba Pharmaceuticals (PTY) Ltd. Annie's group will have to investigate the affinity of the novel compounds for specified targets in cancer cells. The binding targets for this work are tubulin, carbonic anhydrase (CA) II, IX and XII, pyruvate dehydrogenase kinase (PDHK) I and II, as well as kinesin motor proteins (KMP). These targets are known agonists of mitosis in cancer cells and blocking their production or metabolic actions is one way to prevent the cancer cells from multiplying and metastasising. André's next step is the use of microarray techniques to examine the effects of the drugs on potential target genes. *In vitro* cellular and molecular studies will be conducted to elucidate each compound's signal transduction mechanism and to verify their potential anticancer activity *in vitro*. The work will take another five years before live studies can start.

While the search for cures continues for scientists such as Annie and her team, an ironic twist of medical fate has seen an upsurge in the number of women opting for bilateral mastectomies as a preventive strategy [7,8]. In the meantime, health advocacy groups promote early detection as our best hope for minimising breast cancer's potential damage. For most women, though, the 'at least we caught it early' platitude does little to comfort or to quell fears. The design of drugs using computer modelling is one way in which scientists attempt to provide women with options for the treatment of breast cancer. But, yes, every woman's best hope still lies in finding the lump early. This means that – at least for now – the success of our campaign against breast cancer literally rests in our own hands. □

Catherine Govender is a lecturer in the Department of Natural Sciences at the University of Pretoria.

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Carbon isotopes, photosynthesis and archaeology

Knowing the pathways of carbon in photosynthesis allows us to reconstruct early human diets. *QUEST* explains how this technique is used in archaeology.

In Bob Brain's detective story he deduced that early ape-men used the bones found in the middens around their caves not as weapons, but as tools for digging up roots and other foods. This was one line of evidence that suggested that these ape-men and, indeed early hominins, were prey rather than predators.

However, there is another way that we can find out about prehistoric diets. Archaeologists Nikolaas van der Merwe and Judy Sealy have spent many years carrying out research on stable isotopes, which can provide us with information about the diets of early hominins.

Isotope: One of two or more atoms of the same element that have the same number of protons in their nucleus, but different numbers of neutrons. Most elements in nature consist of a mixture of isotopes.
Stable isotope: These are isotopes that do not show radioactive decay. Most naturally occurring isotopes are stable.

Photosynthesis and the study of diet

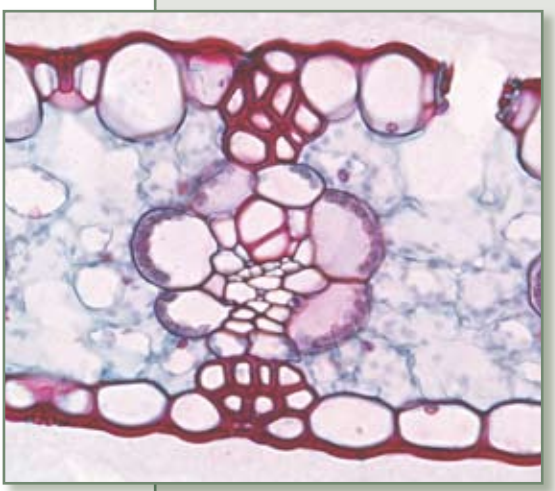
The element carbon (C) occurs in three main isotopic forms: ^{12}C, ^{13}C and ^{14}C. The first two isotopes are stable, while the third disintegrates radioactively over time. All three isotopic forms react chemically in the same way, but because their atoms have different atomic weights and are of different sizes, they react at different rates. In 1961 the scientist Melvin Calvin won the Nobel Prize in Chemistry for his description of the chemical pathway followed by carbon during plant photosynthesis. Archaeologists use the behaviour of the different carbon isotopes during photosynthesis as a way of measuring the diet of prehistoric peoples.

In order to do this, they rely on the fact that different chemical and metabolic processes change the ratios between the isotopes in characteristic ways. We now know that not all plants follow the photosynthetic pathway that Calvin first described. It is this that makes dietary tracing possible, by looking at the different pathways and the different ratios of the three isotopes that each pathway yields.

All isotopes undergo what is called isotopic fractionation, which is a change in the isotopic ratios between materials that is due to the different rates at which isotopes undergo chemical reactions. Carbon isotopes are strongly fractionated during photosynthesis, when plants metabolise carbon dioxide. There are three types of photosynthesis found in the plant world, which are called the C_3, C_4 and CAM pathways. During the first step of photosynthesis, C_3 plants convert carbon dioxide from the air into a phosphoglycerate compound with three carbon atoms. This pathway was first identified in spinach, algae and barley in 1948.

Much later, by 1965, a different photosynthetic pathway was identified in Hawaiian sugarcane. This is the

Kranz leaf anatomy refers to the circular arrangement of bundle sheath cells in a leaf, which can be seen in cross-section under a microscope.



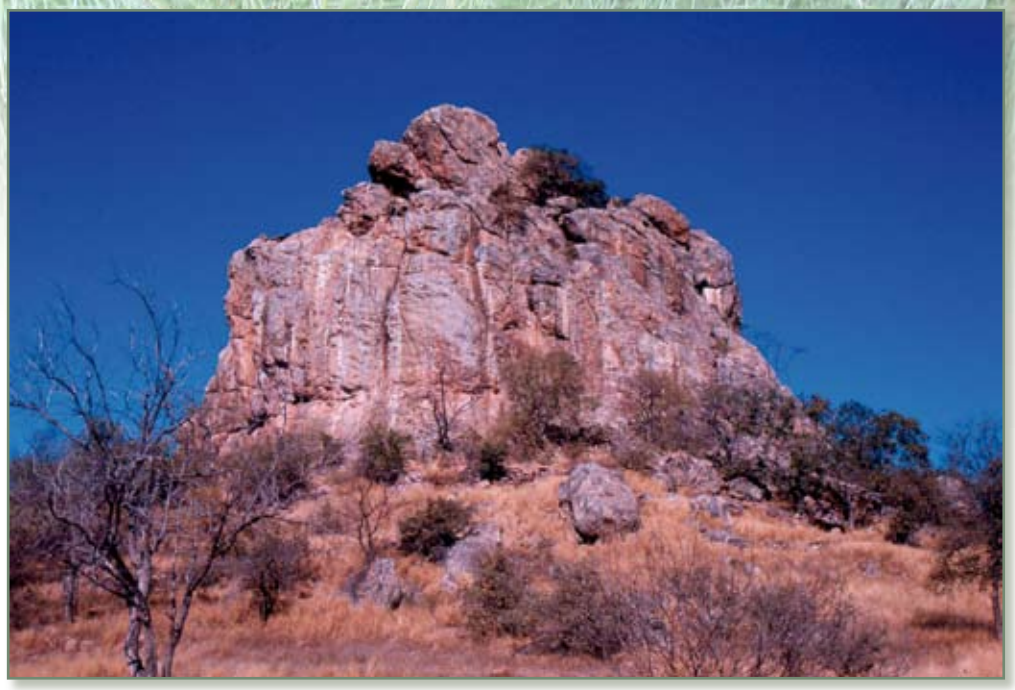
The arrangement of bundle sheaths in Zea mays *as seen under a microscope.*
Image: Paul Schulte, University of Nevada

C_3 and C_4 plants

Most of the plants in Europe and North America are C_3, while most of the grasses and a few shrubs in the subtropical, savannah and arid regions of the southern hemisphere are of the C_4 type. Grasses growing in salt marshes or along the ocean are also often C_4 species, even though the climate may be temperate. In contrast, all trees and most shrubs are C_3 plants, as are grasses from temperate regions and tropical forests.

It appears that most C_4 plants are grasses from hot climates. However, tropical forests, which grow in some of the hottest places on Earth, have no C_4 plants in them. So it would appear that C_4 photosynthesis is a complex adaptation to environments that have a growing season that is subject to strong radiation from the sun. A tropical forest is shaded.

C_4 plants are highly efficient at processing carbon. They use less time and less water to convert a given volume of carbon dioxide into plant matter. The net result of plant respiration, which takes place in darkness, is carbon dioxide. However, in the light, many plants not only absorb carbon dioxide and convert it to plant matter, but also absorb oxygen and release large amounts of carbon dioxide through the breakdown of their own tissues. This second process, known as photorespiration, occurs at a lower rate in C_4 plants, which accounts for their greater efficiency in processing carbon. This obviously gives C_4 plants an adaptive edge in environments that have strong sun, poor water supplies or a combination of the two. The appearance of C_4 plants in so many parts of the world and in so many plant families also means that this adaptation has evolved several times in different places in response to environmental pressures.



Right: A view of Kgopolwe – the archaeological site is in the foreground of the photograph. Image: Nikolaas van der Merwe

Right below: An aerial view of the Kgopolwe archaeological site – home of African farmers 1 000 years ago. Image: Nikolaas van der Merwe

conversion of carbon dioxide to dicarboxylic acid, a four-carbon compound – the C_4 photosynthetic pathway. The details of this pathway were then described in Australian sugarcane and shown to occur in several other species of grasses. This becomes particularly important to human diets because the staple cereals of the Americas and Africa are maize, sorghum and millet. Even more important was the discovery that the grass species that have Kranz leaf anatomy all have C_4 photosynthesis.

The CAM pathway (which stands for crassulacean acid metabolism) is found in succulents, such as cactus plants, or the plakkies and sour figs that are common in the Cape. This pathway, however, is of little interest in the study of prehistoric diets.

What is important is the fact that C_3 and C_4 plants fractionate carbon isotopes in very different ways.

Stable carbon isotopes as food tracers

The first clue that stable carbon isotopes could be used as food tracers came from research on marine animals in 1964, when PL Parker noticed that marine animals cover the same range of isotopic values as the foods that they eat. We now know that the 'isotopic signature' of food is passed on to consumers. As this food is metabolised, the carbon isotopes may be fractionated yet again before they are stored in the tissues. This makes it possible to determine, for example, the proportion of C_3 and C_4 plants in the diet of a herbivorous animal. The sample material can be hair, skin, bone, meat or horn as long as the fractionation factor of the material is known.

Essentially this means that living organisms are considered as carbon isotope separators so each tissue type has its own characteristic fractionation factor.

Human diets

The application of stable carbon isotope measurements to the study of human diet came about more or less by accident. In 1970, Nikolaas van der Merwe was excavating a group of Iron Age sites at Phalaborwa – among these sites was Kgopolwe 3, at that time the oldest known Iron Age site in South Africa, occupied approximately 1 000 years ago. Van der Merwe found a human male skeleton in an ash heap, which seemed to be out of place for a number of reasons.

The body had been, as Van der Merwe puts it '… rather casually disposed of, instead of being tightly flexed and buried under the floor of the owner's hut, as is customary ▹▹

The skeletal remains of the eleventh-century inhabitant of an Iron Age village, excavated by Nik van der Merwe at Kgopolwe 3, near Phalaborwa, that posed an anthropological puzzle. Image: Nikolaas van der Merwe

The diet of *Australopithecus africanus* at Sterkfontein

Understanding the behaviour and ecology of early hominins is critical to understanding how humans evolved from apes. For example, how and why did tree-climbing apes with diets of forest plants evolve into bipedal foragers with omnivorous diets?

Since the Taung child was first described by Raymond Dart in 1925 there have been many different theories about the diet of *Australopithecus africanus*, most of which contradicted each other. Dart himself thought that the australopithecine diet included various insects, rodents, eggs and small antelope, basing his ideas on what the environment and climate was like during the Plio-Pleistocene. He, of course, later described *Australopithecus africanus* as a homicidal hunter with an osteodontokeratic culture, an idea laid to rest by Bob Brain.

Direct evidence of the diets of early hominins around 2 Ma is scarce. Cutmarks on bones have been found at a number of sites and recent evidence is that one or more hominins at the Swartkrans and Drimolen sites used bone tools to crack open termite mounds.

At some stage in their evolution hominins started to eat a larger component of their food from the savannahs, specifically animal food. Scientists have hypothesised that the increases in brain size that are evident through evolution required an increasing amount of high-nutrient animal foods, because the gut became smaller as the brain became larger. This progression from being herbivores to being omnivores as brain size increased can be studied using isotopic dietary chemistry.

Nikolaas van der Merwe and his colleagues have extensively investigated the carbon isotope ecology of *Australopithecus africanus* at Sterkfontein, using tooth enamel. Their results show that australopithecines were unusually generalised feeders. The research suggests that they ate a large component of C_4 – based foods. This could have included C_4 grasses and sedges and/or the insects and vertebrates that eat these plants.

The most interesting finding was the variation in the C_4 dietary component – at Sterkfontein itself the range between individuals was between 30 and 60%. If the results of four specimens from Makapansgat are added, this variation is between 0 and 60%. This variation is wider than any that has previously been observed for any other species of hominin, or indeed for any other non-human primate, fossil or modern.

The importance of this is that this very varied diet showed that *Australopithecus africanus* was an exceptionally opportunistic feeder – 'the ultimate in hominin adaptability'. From this research we know that hominins foraged on savannah for a significant part of their diet by about 3 Ma.

Left: Dr Phillip V Tobias with the Taung child A. africanus. Image: Wikimedia commons

for men buried inside an Iron Age settlement in this area.' Van der Merwe also thought that the skull looked more like that of a large Khoisan man than of a man from one of the Bantu peoples.

The skeleton was indeed that of a Khoisan man, which raised the question of what this man was doing in a Lowveld Iron Age village. The Khoisan generally remained as hunter-gatherers or herders, while their Iron Age neighbours were farming. In 1970 it was not well known that the Stone Age Khoisan peoples of South Africa were often absorbed into the settlements of their Iron Age neighbours, so Van der Merwe and his co-workers found it difficult to account for this skeleton. When the archaeologists applied the technique of measuring carbon isotopes to this skeleton, as part of radiocarbon dating it, they found evidence that suggested that the man had been a sorghum (C_4 plant) eater. However, nearly all the grasses in that region of the Lowveld are C_4 plants, so anyone who lived there, whether a farmer or a hunter-gatherer, would be likely to have isotope values that would suggest that they ate animals that grazed on these grasses. So, although the man was a Khoisan, he may or may not have eaten sorghum.

The findings remained puzzling until new research from North America on skeletons of American Indians started to give some clues. Archaeologists wanted to know when maize agriculture was introduced to the New York area – maize is a C_4 plant and was introduced to a predominantly C_3-plant environment. They assumed that the arrival of maize in an environment dominated by C_3 plants would make a difference to the isotopic composition of the body tissues of the inhabitants of the area, which is exactly what they found. Early, pre-maize skeletons had different carbon isotope values to later skeletons in the time after the introduction of maize. This opened the way to the study of human diet by means of carbon isotope measurements.

In order to assess the proportion of C_3 and C_4 plants in human food webs, it is necessary to know how human metabolism affects isotope ratios. The most common sample material that archaeologists can use is human bone, which consists of collagen – a soft protein tissue – and apatite (calcium phosphate). The rate of turnover of collagen in adults is very low so the carbon that it contains comes from food that was eaten over a long period of time, at least several decades. Human adult collagen is also inert: it does not exchange carbon with air or other organic materials in archaeological deposits, which adds to its value for analysis. □

Judith Sealy is professor and head of the Deparment of Archaeology at the University of Cape Town. Her research interests include using stable isotopes to look at ancient diets, hunter-gatherer archaeology from the period of the emergence of modern humans to the recent past and the beginnings of food production in Africa.

Nikolaas van der Merwe is Emeritus Professor in the Department of Archaeology at the University of Cape Town. He is a forensic scientist who has become interested in using stable isotopes to study diets in prehistoric times.

Further reading

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Hominin diets in East Africa

All the original work on hominin diets has been from South Africa and has shown that although there was variation in individual diets, there were no marked differences between the diets of different species.

Now, isotopic analysis of specimens from Olduvai in Tanzania show that two species, *Homo habilis* and *Australopithecus boisei* had markedly different diets.

Van der Merwe used analysis of tooth enamel to look at the diets of five hominin specimens from Tanzania.

A relatively small sample of tooth enamel provides an assessment of the average diet of an individual during the time when the enamel was laid down. The two specimens of *Australopithecus boisei* from Tanzania had far larger C_4 components in their diets than found in all other hominin specimens so far analysed. This led Van der Merwe and his colleagues to wonder exactly what this hominin's diet was.

The C_4 food available to these early hominins included grasses, some sedges and a variety of animals (invertebrates, reptiles, birds and mammals) that ate C_4 plants. Earlier research suggests that access to edible C_4 plants was rather restricted in a dry environment, but large wetlands elsewhere in southern and eastern Africa would have offered hominims access to a greater range of C_4 plants. At 1.8 Ma there were extensive wetlands on the eastern side of the ancient lake Olduvai, where a river entered the lake from the Ngorongoro mountain range, providing access to wetland (C_4) plants.

By looking at fossil plants in the area and also at modern C_4 plants from wetland areas in modern Botswana, Van der Merwe and his colleagues were able to conclude that *Australopithecus boisei* had a diet that largely consisted of wetland plants and, in particular, a species of papyrus. Unlike the grasses, the papyrus species are evergreens and are still eaten today by people who live around wetlands in Botswana.

The plant has nutritional qualities that compare quite well with the modern potato – containing more carbohydrates and fats, but rather less protein. About 2 kg of raw papyrus could supply the daily energy requirements of a modern human adult, but only if modern humans had the intestinal enzymes and bacteria required to digest raw cellulose. Apes have this, but we do not. However, it is quite possible that early australopithecines still had these enzymes and bacteria.

It's unlikely that these early hominins had a staple diet of raw papyrus, but it is a strong candidate for a major role in the species' diet. The plant is prolific and perennial, potentially providing year-round food.

Professor Van der Merwe drilling into the tooth enamel of a hominin specimen from Tanzania.
Image: Nikolaas van der Merwe

Papyrus is a prolific plant.
Image: Wikimedia commons

Teaching and learning about EVOLUTION: Part 1

George Branch has been teaching evolution at university level for many years and is aware of the controversy surrounding teaching the subject at schools.

No topic in biology is more controversial than evolution; and no topic is so fundamental to understanding biology. In the view of Kenneth Miller (2007): 'In the minds of many, evolution remains a dangerous idea. For biology educators, it is a source of never-ending strife'. My own view is very different, for I have taught evolution to university students for 40 years with a sense of joy and awe: more than any other subject, it engages students with critical thinking, compels analysis of evidence and forces contemplation of the bigger issues of life. In this year, the 200th anniversary of Charles Darwin's birth, school teachers in South Africa have been challenged with the introduction of evolution as a formal part of the biology curriculum. And a challenge it is indeed: many teachers have not formally been trained in the subject, are pondering what approach to take, and fear the controversy it may engender. For me, it has been an exhilarating experience meeting and running workshops with teachers, to see the subject through the fresh eyes of teachers at the coalface.

In teaching evolution, I believe there are five components that must be covered:

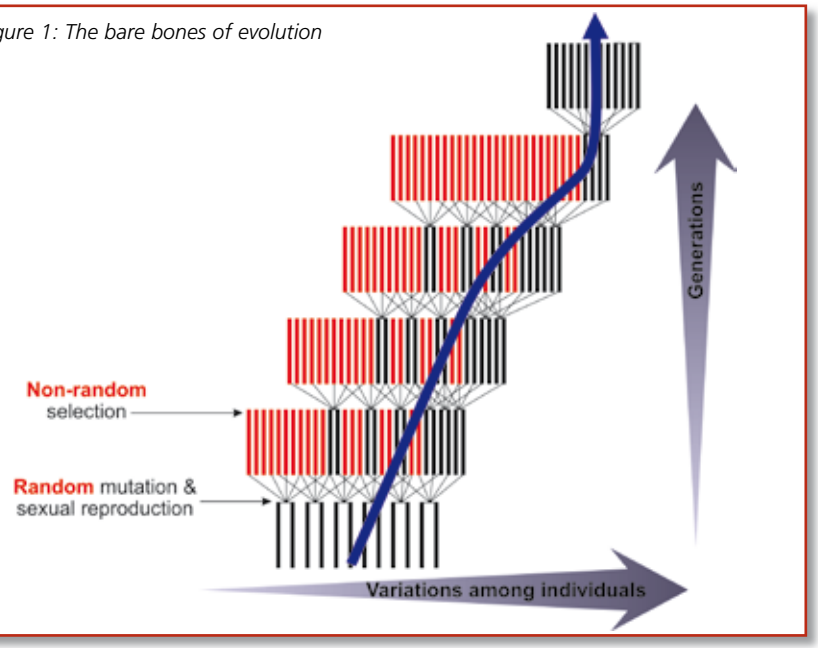
1. Understanding the basics of what Charles Darwin's ideas entail.
2. Testing the concept of evolution and the mechanism proposed by Darwin.
3. Appreciating how science is continually advancing, adding new ideas.
4. Grasping the relevance of evolution in our modern-day world.
5. Exploring the controversies and testing alternative views against the evidence.

In this article, I cover the first two and the last two aspects, leaving for a follow-up article the controversies and how I believe they should be handled.

A summary of Charles Darwin's theory

Theory	Evidence then	Evidence now
More individuals are born than survive to reproduce	Then	
Variety exists among individuals of a species	Then	
'Fitter' individuals are more likely to reproduce = 'survival of the fittest': Natural selection eliminates less well-adapted individuals		Now
If characteristics are inherited, species slowly evolve = adapatation, or 'micro-evolution' eventually even giving rise to new species = speciation, or 'macro-evolution'		Now

Figure 1: The bare bones of evolution



The basics of Charles Darwin's ideas

Many people before Charles Darwin believed in the *concept* of evolution – that species change over time and adapt to the environment – but Darwin's great contribution was developing a plausible *mechanism* for how it takes place. I find it useful to distinguish the two, because while there is universal agreement among biologists that evolution is a process that has and is taking place, there are still today many refinements to Darwin's ideas about the mechanisms that are being added. Darwin's ideas about the mechanism can be summarised in the four simple statements in the table on the left.

Read these carefully. It's hard to disagree with any of them. When Darwin was alive he had hard evidence of the first two. We now have strong evidence for all four. The ideas are deceptively simple but enormously powerful in providing a natural mechanism for how and why species change over time. In the short term, they explain change within species as they adapt to the environment – which some prefer to call 'micro-evolution'. But there is no reason why the process should not lead to the development of populations so different from the parent species that they can become separate species. This is speciation, called 'macro-evolution' by some, although I personally avoid the term because of ambiguities about what it means and because the processes leading to speciation are not necessarily different in kind from adaptation within the species.

Figure 1 shows the process over time (generations), and I often tell my

students that if they understand this figure they have grasped the essentials of Darwin's ideas.

At the bottom of the figure are lines representing 12 individuals – in male-female pairs – that vary in some characteristic (perhaps ranging from slow-moving on the left to fast-moving on the right, for example). These parents produce a range of offspring, which also vary among themselves, partly because they may contain some 'new' mutations and partly because they share their parents' characteristics. Natural selection 'prunes out' individuals – say those that are slow-moving – leaving the next generation with mainly fast-moving individuals. The process is repeated over generations, progressively changing the nature of the species. Note that whereas the formation of mutations is a random process (new mutations may by chance be good, bad or indifferent for the chances of survival of the individual offspring), natural selection is clearly not random, so the overall process of evolution is not random either.

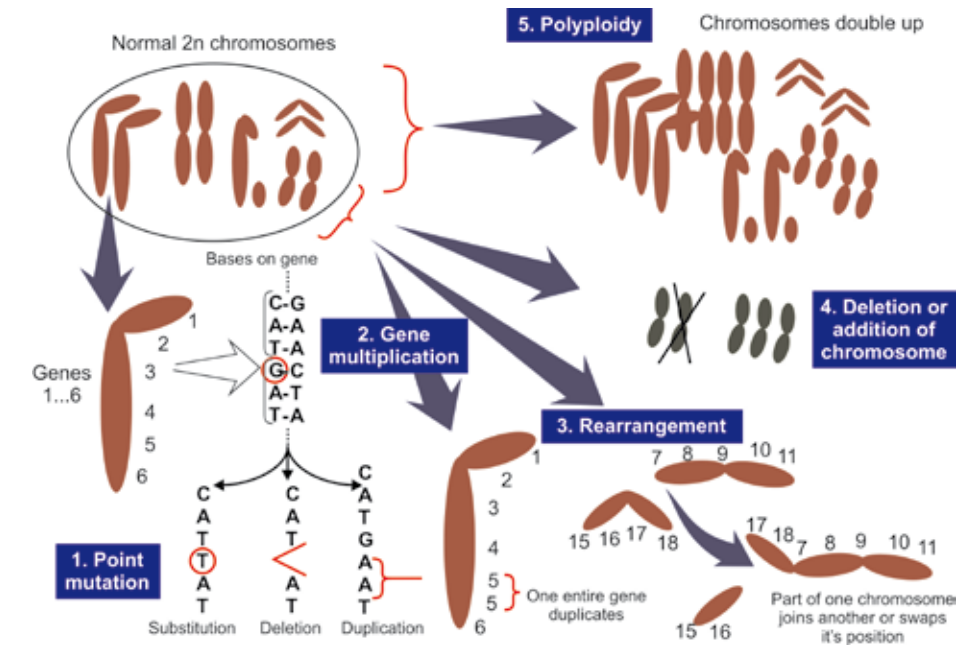
In addition to natural selection (the action of environmental factors in selecting for particular varieties), Darwin also wrote extensively about sexual selection – how the characteristics of individuals of one sex may make them more attractive to the opposite sex (like the long tails of male widow birds or peacocks), or better able to compete with members of their own sex when seeking mates (like the antlers of male deer). As one of my first-year students memorably commented in an exam: 'It's the horniest male that wins…'

Darwin's greatest difficulty was a lack of understanding about inheritance. Gregor Mendel did publish his ideas in Darwin's lifetime, but Darwin failed to grasp their significance. Research has since unearthed multiple ways in which genetic variations can come about (Figure 2).

Most familiar are point mutations, which change one individual base within a gene (by substitution of a new base, deletion or multiplication of the base), sometimes altering the amino acids in the resultant protein. Genes may duplicate themselves or swap their positions within chromosomes. Whole chromosomes may be deleted or duplicated, and even the entire chromosomal compliment can multiply in a process called polyploidy. All these genetic changes can alter the nature of the individual.

Two of these genetic changes are

Figure 2: Different types of mutations.



particularly interesting. When a gene is duplicated, one may continue its original function while the other is free to mutate and can lead to the formation of a 'new' gene with a completely different function. It seems that many of our own genes arose this way, including those involved in the complex sequence of reactions that takes place when our blood clots.

At first sight, polyploidy just looks like a doubling up of the chromosomal complement without the generation of anything 'new' in the genotype. But in reality the process seems immensely important in the creation of new species – particularly new species of plants. There is strong genetic evidence that large proportions of 'new' plant species are formed by a combination of hybridisation between different species and a doubling up of chromosomes. This seemingly unlikely combination of events forms offspring that have a unique genetic composition and cannot mate with either of their parental species, effectively 'instantly' becoming a new species. If we doubt the importance of this, ponder the fact that bread wheat – one of the most important food sources today – arose by two separate events of hybridisation-induced polyploidy.

Such modern developments in genetics throw light on how inherited genetic changes allow species to adapt and even how new species come into being – about which Darwin could only guess, despite the title of his book *The Origin of Species*.

Testing Darwin's ideas

In science, ideas are of no value unless they are testable (falsifiable). In Darwin's day it was easy to test the first two of his ideas. Variety is evident in all species; and it is easy to calculate what would happen if all individuals that are born were to survive to reproduce. For example, flies can achieve 17 generations in a year: if 30 females mated and all the offspring subdivided and bred unchecked for the 17 generations, there would be 12.9 million million million million flies produced (equivalent to a layer 2 km deep over the whole world). Mercifully, there aren't: so we can safely assume Darwin was right.

As a classroom exercise it is possible to explore family trees to demonstrate the principles of variety among individuals, survival-to-reproduction, and inheritance of family characteristics. I normally take a whole lecture to get students to discuss among themselves what lines of evidence they could seek to test Darwin's ideas – and the concept of evolution as a whole. As a prompt, one can ask: 'If evolution occurs, then …'. This leads to all sorts of evidence that can be sought in the natural world, which should exist if evolution takes place.

For example, 'If evolution occurs as Darwin proposed, then … not all individuals that are born should survive to reproduce.' That much is so▹▹

Figure 3: The bottlenosed dolphin has vestigial remnants of all three elements of the pelvic girdle – mementoes of ancestors that possessed the hind limbs that have been lost in whales and dolphins.

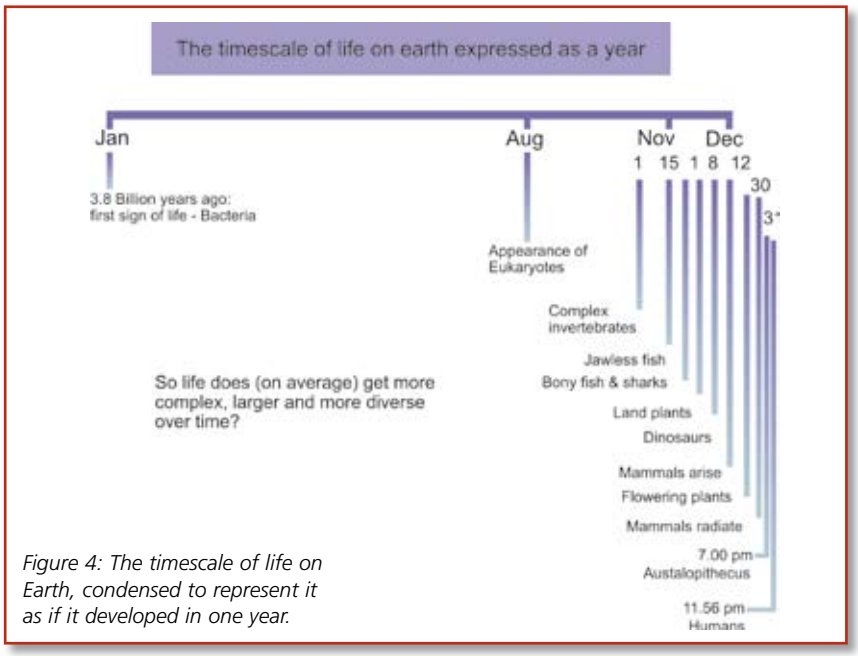


Figure 4: The timescale of life on Earth, condensed to represent it as if it developed in one year.

obvious as to be almost self-evident.

Over the years, my students have come up with 14 different, and largely independent, lines of evidence that can be used. Space doesn't permit examination of all of them, but they included expected trends in the fossil record, modern changes in the nature of species ('evolution in action'), the existence of intermediates between species (and between major groups of organisms such as reptiles and mammals), population studies on survival, genetic causes of variety, embryology, comparative morphology, comparative genetics, biogeography (patterns and explanations for where species live), taxonomy (classification of species), geology and dating of the Earth.

There are examples of modern-day 'evolution in action' in all textbooks. The change of peppered moths from populations dominated from pale forms to those dominated by dark (melanic) forms is a classic because it was one of the first to be recorded. But there are now hundreds of cases. Challenge students to come up with cases drawn from their own knowledge. Examples are development of drug resistance in the tuberculosis bacterium; the formidable adaptation of HIV to drugs; evolution in insects of resistance to insecticides; and human incidence of sickle-cell anaemia in areas with high malarial infection.

Let me dwell on two of my favourite tests of the phenomenon of evolution. First, the existence of vestigial (or rudimentary) organs is to me one of the most convincing pieces of evidence that evolution is a fact. Consider a species of fish that lives solely in total darkness in caves and has rudimentary, stunted, non-functional eyes that cannot detect light. Why possess such a useless structure? If this species was created as it now is, and did not evolve from an ancestral species, 'blind' eyes are hard to explain. Personally, I would find it hard to accept that God would create species like that. If, on the other hand, the blind cave fish arose from a sighted ancestor that lived in sunlit waters, then possession of eyes would not only be understandable but expected. Also to be expected would be the loss of sight and the progressive degeneration of eyes in pitch-dark caves where eyes would not only be useless but a waste of energy. Natural selection would favour individuals that developed mutations eliminating the eye. Similarly, one could ask 'Why does a dolphin have the rudiments of a pelvic girdle buried in its hindquarters, when it has no hind limbs?' (see Figure 3).

Second, the fossil record also provides opportunities to test evolution. At least five things would be predicted of the fossil record if evolution occurs. Over time, there should be: (1) increasing complexity; (2) greater diversity; (3) overall increase in size; (4) more species that are similar to modern life; and (5) existence of intermediate forms. Indeed, the relative appearances of different major groups of animals and plants do reflect an increase in complexity, diversity and size, and there are many examples of intermediate stages, between – for example – fish and amphibians, dinosaurs and birds, and reptiles and mammals. Our own Karoo is world-famous for the 'mammal-like reptiles' that are bridges between reptiles and mammals. Figure 4 provides some perspective.

If we imagine the time-course of life on Earth being condensed into one year, three things always strike me. First, life – in the form of single-celled prokaryote Bacteria or Archaea – seemingly appeared on Earth around 3.8 billion years ago, relatively soon after the creation of Earth itself, which is dated at about 4.7 billion years ago. Second, for a very long period of time, there was only single-celled life, and then relatively modern-looking multicellular life abruptly burst on the scene. Third, our own human species is a real

Johnny-come-lately, emerging at 11.56 pm on the last day of this hypothetical year-of-life. I am always awed and humbled by this latter fact: by the immensity of events that preceded us, and by the awful responsibility we carry as the only sentient being both capable of destroying Earth's ecosystems and of contemplating means of avoiding that.

In short, *all* lines of evidence that have been used as tests uphold the idea that evolution does occur, and that Darwin's fundamental ideas about the mechanism are correct.

Appreciate how science is ever on the advance, adding new ideas

Darwin may have been vindicated by multiple lines of evidence, but his ideas were, nevertheless, far from complete: many other mechanisms have since been added to complement his visionary views. By far the most important have been in the field of genetics, which has generated an understanding of inheritance and an independent means of testing evolutionary ideas. After Darwin's insights – regarded as the 'first wave of understanding', genetics constituted a 'second wave'. But I would like to concentrate here on what some call the 'third wave', which is the revolutionary field of 'evo-devo' dealing with the evolution of embryological development. The miracle of embryology, in which a single-celled egg is transformed through organised stages into an adult stage with all its parts functioning in the correct time and place has taught us much about how evolution operates. More importantly, it has opened a new understanding of how quite minor genetic changes can bring about major changes in body form.

'Evo-devo' has revealed the presence of 'master-switch' or 'hox' genes that control by promotion or inhibition the expression of a cascade of other genes responsible for the assembly of the developing embryo. Every cell in the embryo has the full complement of genes. But it is the expression of particular genes in particular cells at particular times and places that regulates the development of the body. Imagine, for example, the development of an insect's body. In the head of the developing embryo, a hox gene is expressed that 'turns on' other genes controlling eye development. Further back in the body other hox genes may repress eyes but initiate limb formation. In the abdomen, both eyes and limbs may be inhibited (Figure 5).

Figure 5: In different parts of the insect body, 'master-switch' (hox) genes are activated (or switched off), controlling other genes that produce particular structures in different parts of the body. Here, the hypothetical action of three hox genes is illustrated for an insect body.

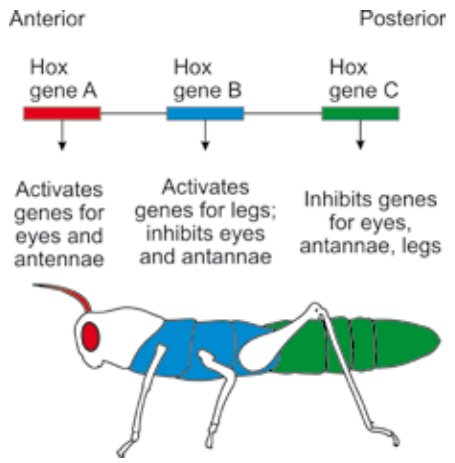


Figure 6: Neoteny in 'glow-worms': the premature development of sexuality and suppression of later stages, generating a grub-like adult that is fully mature – shown here with one of the snails on which glow-worms feed.

There are several extraordinary things about hox genes. First, they are exceptionally constant across major groups of organisms. For example, the hox gene regulating eye development (named 'Pax-6') is virtually the same in humans, molluscs, fish, birds, flatworms, bristle-worms and flies. Even although the eyes that are produced may differ radically in these very different animals, the 'master-switch' genes are nearly identical. Second, and as a consequence of this, the 'eye' hox gene can be extracted from, say, a mouse, and used to initiate development of a fly's eye in a fly. Third, if hox genes are experimentally activated in a 'wrong' part of the body, they will induce the 'wrong' body parts there: an eye can be formed on the abdomen, or a leg on the head.

In short, hox genes are in charge of controlling the embryological development of the body, initiating or inhibiting particular body parts in particular places and in the correct sequence. There are two enormous implications for the process of evolution that arise from this. First, the deep similarity of hox genes among a wide range of species implies that these genes have been shared over hundreds of millions of years of ancestral history. Second, very minor change in the activity, timing or place of expression ▹▹

Examples of the application of evolutionary principles in the modern world

1. Resolving legal issues – DNA fingerprinting
2. Tracing evolutionary origins of diseases and developing treatments
3. Genetic modification of organisms – e.g. generation of insulin by bacteria
4. Selective breeding of plants and animals
5. Warfare – biological pathogens and mutation-inducing chemicals
6. Resistance of insect pests to insecticides
7. Eugenics – countering genetic deficiencies
8. Justifying antisocial behaviour because of genetic predisposition
9. Genocide or racialism justified by supposed evolutionary superiority

of a hox gene can have a profound influence on the structure of an organism. It becomes, for example, easy to understand how a creature such as a centipede with its myriad of legs, might have become transformed into an insect that has only three pairs of legs. But we do not have to settle for a hypothetical case such as this: there are modern-day examples of creatures that have become radically modified by a change in the sequence of the expression of hox genes. One case is the 'glow-worm', which is actually the female of a beetle, in which the expression of wings has been suppressed by inactivation of the gene responsible for wing formation, and the premature activation of genes responsible for sexual maturity. The result is a creature that is not at all 'beetle-like', but resembles a grub that never develops its adult beetle features and becomes sexually active at a premature stage – a process called neoteny (Figure 6).

So as science has advanced, new ideas have been added to Darwin's core ideas, reinforcing, strengthening and expanding them.

Grasping the relevance of evolution

When first confronted with the idea of evolution, students and pupils often express excitement about the concept but regard it as abstract and distant from their everyday lives. Nothing could be further from the truth, and communicating this and getting young minds to appreciate the applications of evolution is an important part of education.

This can be used as a participative part of a course on evolution, in which scholars offer their own examples, research them, and present them. Their thoughts can be stimulated by asking them to work in pairs to come up with one positive and one negative application of evolutionary principles. Above is a list that resulted from one class of scholars, with positive outcomes being shown in green and negative ones in red.

In a world where HIV is mutating at a ferocious rate and thwarting efforts to find a vaccine or an effective drug, where we have the capacity to alter our own genetic composition but feel nervous of the moral implications, where we can genetically modify bacteria to produce life-saving insulin but balk at altering food crops, there is not only abundant evidence of the relevance of evolution, but plenty of scope for discussion – as evidenced by the fact that several topics ended up being a mix of green and red – neither all good or all bad.

Conclusions

1. The *process* of evolution is an established fact. It has been exhaustively tested against multiple lines of evidence and upheld. Species do evolve.
2. Darwin's ideas on the *mechanism* are equally well supported, but are clearly incomplete and have since been supplemented and supported, particularly by genetic and developmental research.
3. Science doesn't have answers to all questions, even in the material realm, but mysteries are a challenge for science, not a weakness … the fact that research in the field of Evolutionary Biology is so active shows we have much to learn; but the base on which we build is still founded on Darwin's central ideas.

There is still much material for debate. Is it right or wrong to screen unborn babies for genetic defects? What actions should be permissible if we do so? How can we as human beings be almost unanimous in supporting the use of 'genetic fingerprinting' to determine with certainty the guilt or innocence of people charged with crimes – and yet be resistant to accepting the concept of evolution without which this process would be impossible? In the next edition of *Quest* we will return to topics such as these – and the bigger question of how teachers might handle evolution and religion – in a second part to my pair of articles on 'Teaching Evolution'. □

George Branch is Emeritus Professor in the Department of Zoology at the University of Cape Town. He is an 'A-rated' scientist and winner of the Gilchrist Gold Medal and the 2006 International Temperate Reef award for life-time contributions to marine science. He has spent a lifetime studying the shoreline of South Africa, and has published numerous scientific articles and books on the subject.

He has spent decades teaching undergraduate and postgraduate zoology students, inspiring generations of young scientists and offering a balanced approach to the science of evolution.

Suggested reading

Carroll S. *Endless Forms Most Beautiful: The New Science of Evo Devo and the Making of the Animal Kingdom*. New York: WW Norton, 2005. (An exciting and lucid account of the genetic control of embryology and its evolutionary implications.)

Dawkins R. *The Ancestor's Tale: A Pilgrimage to the Dawn of Life*. London: Weidenfeld & Nicolson, 2005. (A brilliantly written account of life, starting with humans and tracing backwards through their ancestors, with multiple insights into the evolutionary process.)

Hoagland M, Dodson B. *The Way Life Works*. South Africa: Ebury Press, Random House, 1995. (A superbly illustrated introduction to evolution and biology in general, written for the younger mind, but a delight for 'oldies' as well. Brilliant material for teachers.)

Millar, K. *Finding Darwin's God*. New York: Harper Perennial, 2007. (A great introduction to the controversies, written by a deeply religious person who is a molecular biologist and an authority on evolution.)

What can we learn from human skeletal material?

'You study what? I had no idea that you can make a career out of studying bones!' **Jacqui Friedling** tells us what the bones of the dead can tell us.

Why is it important to study skeletal material?

The comment above was the response I got from a Grade 10 pupil in 2004 when doing the community component of my scholarship. I was shocked to realise that some biology teachers had no idea that biological anthropology was a viable career. Not only is it an exciting field of study, but the amount of information that can be gleaned from the humble bone astounded both students and teachers alike.

> Anthropology is the scientific study of the origins and behaviour of humankind, including the development of societies and cultures.

Skeletons as documents

Skeletons are unique documents of our unwritten past and can provide much information about that past to later communities. Human skeletal remains are more than practical objects of value for scientific research they are also a part of the history and fabric of South African society. Thus the information generated by their study is of great importance to everyone. With this approach to human remains, the remains of our ancestors can help us to better understand and devise possible solutions to the many intractable problems of social behaviour and disease that we currently face.

Researchers Nelson and Jumain (1991) state that we cannot understand the human condition without investigating human biological and cultural behaviour. Our physical and behavioural characteristics are the result of the intermingling of an inherited genome with environmental factors. This is true of all living organisms. For example, environmental forces influence bones and teeth. Bones respond to mechanical forces and thus they change in response to activities and stresses. Bones and teeth can tell us about the lives of earlier peoples.

We can use the study of living people today to reconstruct and interpret activity patterns, the health, the diet and the disease patterns of past peoples and thus get a very real glimpse into what earlier life would have been like.

Cities are urban settlements where populations are concentrated into a small space. In these areas of high population density, there is diversification of labour as people are ranked according to the work they did or their position in their families. These can be seen through examining how and where they are buried and by telltale marks on their bones and teeth.

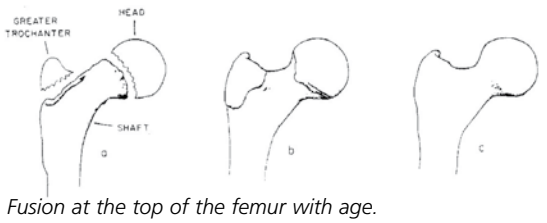
Bone growth

There is considerable variability between men and women in the way that bone grows; also between individuals of the same sex, age and racial affiliation and between individuals exposed to different environments and diets. Although estimates of sex and age can never be exact, errors can be minimised by careful interpretation of the data.

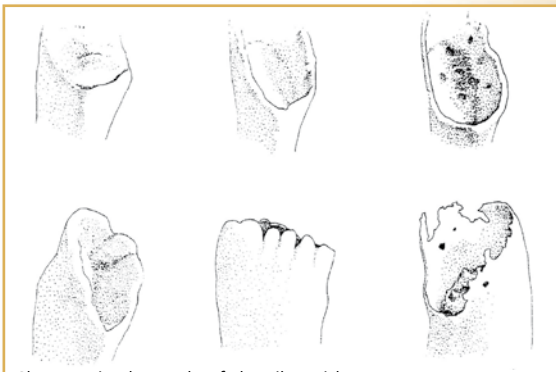
Estimating age at death

To estimate the age at which someone has died, a biological anthropologist looks at morphological features in the skeletal remains. We use what is known about chronological changes that occur in the skeleton. These changes do not occur at the same rates in different bones and structures.

During infancy, most changes involve the appearance and the growth of bones and teeth. During childhood and through adolescence, bone growth, dental eruption and calcification continue. In addition, the epiphyses (growth plates) on the part of the skeleton other than the skull, develop and unite. Between 18 and 20 years of age, most growth is complete, all the teeth have erupted and are fully calcified and most epiphyses are united. After the age of 20, landmarks are provided by the progressive union of the cranial sutures, changes in the pubic bones and changes in the microscopic structure of bones and teeth.



Fusion at the top of the femur with age.



Changes in the ends of the ribs with age.

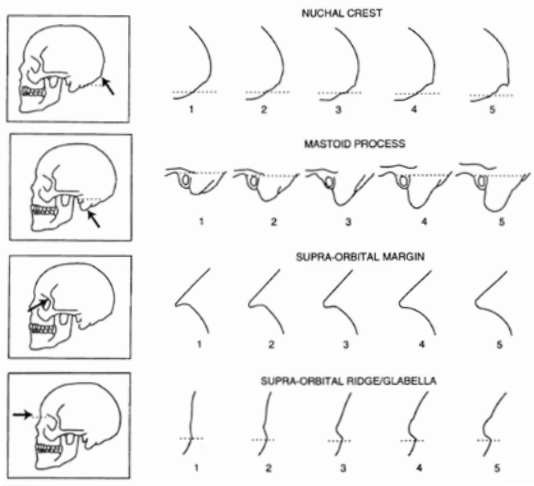
So, there are various ways for ageing a skeleton depending on the presumed age. For example, in children you look at dental development, the length of long bones and whether or not the epiphyses have joined.

In adults you look at landmarks on the pubic bones, the skull, degenerative changes in the bones, the resorption of cancellous bone and dental changes.

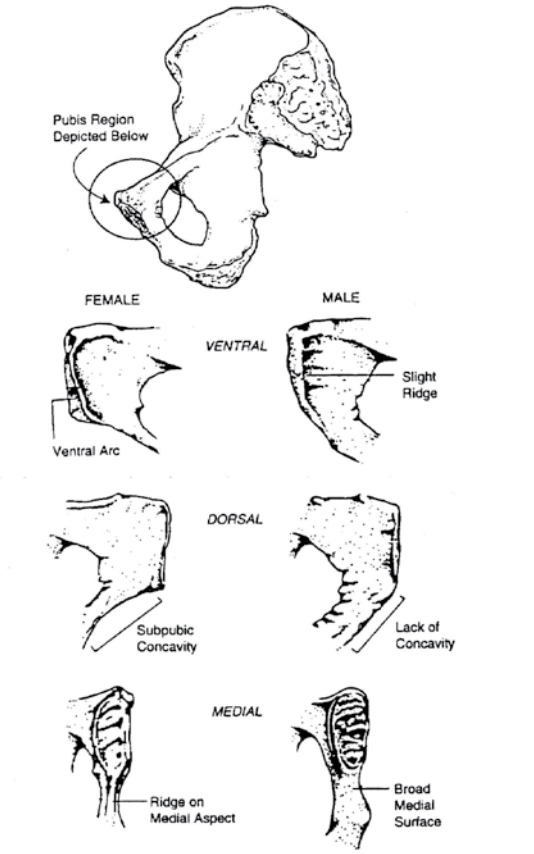
> Cancellous bone is the bone that fills the cavities of the long bones. It is less dense than the compact bone that makes up the outer layer of our long bones.

Determining the sex of bones

Sexual differences begin to develop in the skeleton before birth. Through infancy, childhood and into adolescence, these sexual changes become more marked and so it is easier to sex skeletal remains. The fact that females grow faster and mature earlier than males makes it necessary to consider age when estimating sex in sub-adults (children or adolescents). In sub-adults you use the stage of calcification of the teeth and the stage of maturation of the main part of ▹▹



Estimating the sex of a skeleton using the skull.

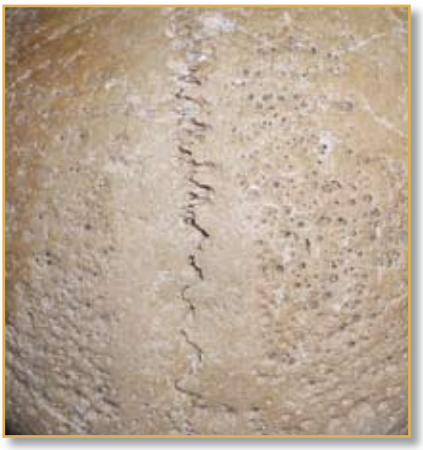


Estimating the sex of a skeleton from the pelvis.

the skeleton. In adults you once again look at the landmarks on the pelvis, skull and long bones.

You can also determine the sex of a skeleton using DNA analysis. This is done by using the amelogenin gene, found on the X and Y chromosomes, using the polymerase chain reaction (PCR). This method is especially useful when examining juvenile or fragmentary remains. However, the bones and teeth (and thus the DNA) have to be well preserved.

PCR (polymerase chain reaction) is a procedure that is used to analyse any short sequence of DNA or RNA. It can be used for tiny samples because the procedure amplifies selected sections of DNA or RNA.



Above left: Porotic hyperostosis – found on the inside of the skull (the cranial vault). Image: University of Cape Town

Above right: Cribra orbitalia – seen on the roof of the eye socket. Image: University of Cape Town

Clues to pathology

Listing and describing the pathological changes on skeletal remains is an integral part of any biological anthropological analysis. As well as the changes resulting from the normal processes of growth and ageing, modifications of the bones and teeth can be produced by cultural practices and pathological conditions.

Certain types of trauma will leave instantaneous signs on bone and teeth (for example intentional mutilation, complete or compound fractures and weapon wounds). However, because the effects of other kinds of trauma – such as stress or fatigue fractures – as well as those of occupational stress and various infectious diseases accumulate over years, they may not be detectable at the time of the individual's death. The impact on the bone would only have been seen if the individual had survived longer. So an individual may have suffered more trauma (of any form) than is shown by his or her bones or teeth.

A compound fracture is one in which the broken bone extends through the skin and can be seen in an open wound.

A stress fracture is one in which the bone may not even appear to be broken, but is damaged by constant, repetitive stress such as heavy loads. These fractures are commonly found in runners.

Diseases that can be seen in the bones

The bones can provide many clues to past diseases, in adults and children. For example, two specific bone deformities called cribra orbitalia and porotic hyperostosis may show that an individual was deficient in iron or simply malnourished and suffering from rickets – a condition in which bone does not develop properly. The bone around the eyes and on the inner surface of the skull appears to be spongy and porous.

Harris lines are seen in the long bones on X-ray (on the left). Image: University of Cape Town

Harris lines are transverse lines that can be seen on X-ray, which are usually found at the ends of long bones. They are generally found in children who have suffered metabolic insults, such as disease and malnutrition. Although we don't know exactly how these lines are formed, Harris lines provide some insight into the stress history of a population or individual.

Other diseases that can be seen in the bones are osteoarthritis, which is

Septic arthritis of the knee joint.

Caries (tooth decay).

Further Reading

Aufderheide AC, and Rodriguez-Martin C. *The Cambridge Encyclopaedia of Human Palaeopathology.* Cambridge University Press,1998.

Larsen CS. Bioarchaeology: *Interpreting behavior from the skeleton.* Cambridge University Press, Cambridge,1997.

a common degenerative joint disease, and infections of the bone (periostitis). Trauma, in the form of fractures, can leave long-term damage to bones.

The teeth or dentition provide physical evidence of dietary and non-dietary behaviour. If dental disease is sufficiently severe, there will be defects in the enamel.

Our lives in our bones

Changes to bones can be used as markers of social status and occupational stress, which can tell us about how a person lived. Only adult bones are useful in this case. The bone changes that are most useful are called enthesopathies and articular modifications. These are seen as rough patches and bone projections where the tendons and ligaments attach to bones. These features develop as a result of prolonged, excessive muscular activity and their location and size on the skeleton can help to show the kind of work that an individual carried out. This helps us to understand the social organisation of work in previous times. □

Dr Jacqui Friedling is a lecturer in Anatomy and Biological/Forensic Anthropology in the Department of human Biology at the University of Cape Town. She also works with the NPA 'Missing person's task team', the SAPS and State pathologists on forensic cases, as well as for private concerns. Her research interests include skeletal biology, forensic anthropology, human variation and adaptation and studies on health, disease, diet and activity patterns in historic populations.

(The schematic diagrams are based on Buikstra & Ubelaker, 1994)

Becoming a biological anthropologist

Biological anthropology (also called physical anthropology) is an interesting mix of social studies and biological studies. The two main areas of study are human evolution and human variation, specifically biosocial variation. Biological anthropologists use the techniques of archaeology to unlock the secrets of the past. Biological anthropologists study nutrition, child growth, health in societies, the genetics of human populations and adaptation to the environment.

You can study biological anthropology at the University of Cape Town. You need a biological BSc or an MBChB to enroll in the honours course.

A replica of Galileo's orginal telescope used for the first recorded astronomical observations I 1609, compared with a modern telescope. Image: Sheffield University

World scientists warn about ocean acidification

World scientists have warned against the omission of ocean acidification from the agenda at the United Nations Copenhagen conference on climate change in December this year. Ocean acidification, one of the world's most important climate change challenges, is expected to cause massive corrosion of our coral reefs and dramatic changes in the makeup of the biodiversity of oceans and to have significant implications for food production and the livelihoods of millions of people.

The warning is made in a joint statement published by the *Academy of Science of South Africa* and the academies of sixty-nine other countries around the world through their membership of the InterAcademy Panel.

Professor Robin Crewe, President of ASSAf, noted 'Climate change is the biggest environmental crisis that the world has ever faced. The anticipated changes to temperature, rainfall and sea level are well known, but a neglected environmental threat is that of ocean acidification. The rise in CO_2 emissions has increased the acidity of the world's oceans threatening coral reefs, marine biodiversity and food security. We urge nations to address this potential environmental catastrophe at the climate change meeting in Copenhagen in December before it is too late.'

The statement calls for world leaders to explicitly recognise the direct threats posed by increasing atmospheric CO_2 emissions to the oceans and its profound impact on the environment and society. It emphasises that ocean acidification is irreversible and, on current emission trajectories, suggests that all coral reefs and polar ecosystems will be severely affected by 2050 or even earlier.

The statement was issued during the UNFCCC conference in Bonn that will ultimately shape the Copenhagen negotiations, where agreement must be reached on carbon emission reduction targets needed to avoid dangerous climate change.

G8+5 meet in Rome

The G8+5 academies' meeting was held in Rome from 26-27 March 2009, hosted by the Accademia dei Lincei. It was appropriate that in the year marking the 400th anniversary of the first recorded astronomical observations with a telescope by Galileo Galilei, one of the earliest members of the Academy, that the meeting should be hosted by Italy. The Academy was founded in 1603 by four young men who were passionate about science. The youngest of them, Federico Cesi, was only eighteen years old. The Academy published Galileo's works and supported him in his disputes with the church.

The Accademia dei Lincei is housed in the 18th century Corsini Palace and boasts a magnificent library and art collection. The Academy also owns the early 16th century Italian Renaissance architectural gem, the Villa Farnesina, which is situated opposite the Corsini Palace and across the road from the Tiber River. The interior is richly decorated with frescoes by great masters, of whom Raphael is the best known.

The G8+5 meeting was attended by Professors Crewe and Diab, with Professor Crewe making a presentation entitled 'Energy Challenges in Africa' and Professor Diab 'Migration in sub-Saharan Africa'. The topic of energy was described by the Minister of Science, Minister Frattini, in his opening address, as 'the most complex challenge of today' and the topic of migration was described as 'the most visible global challenge'. The aim of the meeting was to prepare statements on these topics ahead of the G8+5 Presidents' meeting in Maddalena in Sardinia in July 2009. The meeting closed with the participants having reached agreement on the energy statement but with little agreement between countries in the contested terrain of migration. This latter statement was subsequently withdrawn.

SciFest Africa 2009

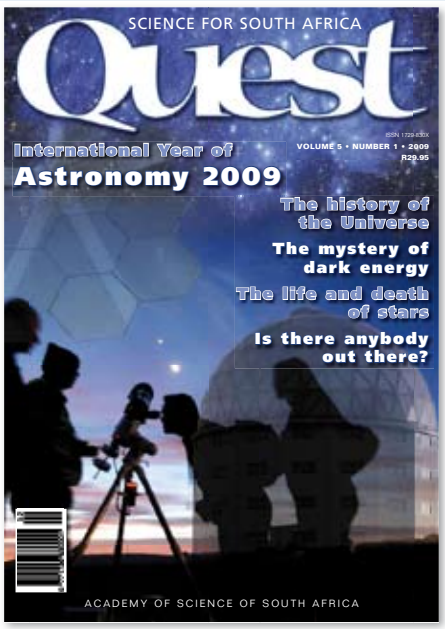
The Academy of Science of South Africa (ASSAf) participated in the annual SciFest, held in Grahamstown from 25–31 March 2009. This prominent national science festival is held annually and is attended by many within the science community. The 2009 festival drew over 68 000 people, mostly students and their teachers.

At the festival, ASSAf showcased its publication *QUEST: Science for South Africa*. The issue taken to SciFest celebrated the International Year of Astronomy, which was widely distributed, along with a subscription form.

The editor of *QUEST*, Dr Bridget Farham, engaged with students and other people who wanted to know more about the magazine. She also gave a presentation titled 'Science is fun', and highlighted some interesting science facts.

Several interesting science events including workshops, lectures, exhibitions, educational theatre, field trips, laser show, high-school quizzes, science shows and tours took place.

Other institutions that were present at the event were the Department of Science and Technology (DST), National Research Foundation (NRF), Council for Scientific and Industrial Research (CSIR), MTN Science Centre, the South African Agency for Science and Technology Advancement (SAASTA) and the South African Astronomical Observatory (SAAO). Algoa and Munghana Lonene radio stations broadcast live from the event.



Shows and exhibitions

Iziko Planetarium, Cape Town

Davy Dragon gets his own weekly Sky Guide Show!

Davy Dragon's guide to the night sky

Until 21 June & from 25 July
Saturday – 12:00; Sunday – 12:00; 16 June – 12:00
Join Davy Dragon as 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.
Especially for children aged 5–10

For the school holidays!

Constellation Board Game Workshop for children

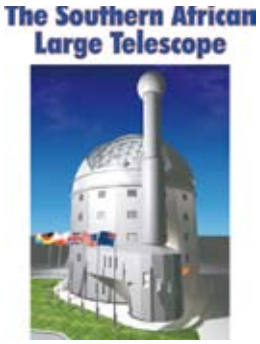
** Make your very own Michael Lion Constellation Board Game!*
Dates: 7 July, 9 July, 14 July, 16 July.
Time: 10:00–12:15 (we start by watching the planetarium show '*Michael Lion and the Star Pictures*') **Age:** 5–7 years *Cost:* R20,00
Tickets available at the Iziko SA Museum's Main Entrance from 30 May (open daily 10:00–17:00)
Please note – numbers are limited, so to avoid disappointment, don't delay!

Michael Lion and the Star Pictures
Once upon a time a little toy lion, called Michael, and his best friend, Bertie, went on a rather magical quest. Along their way the two friends met a few interesting characters and saw some amazing sights. But did they find what they were looking for? Join us and find out for yourself!
27 June–19 July
Monday to Friday – 12:00 & 13:00;
Saturday – 12:00; Sunday – 12:00
Especially for children aged 5–12

For Adults

THE SKY TONIGHT
Ongoing
Saturday – 13:00; Sunday – 13:00;
16 June – 13:00
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.
Suitable for teenagers & adults.

THE SOUTHERN AFRICAN LARGE TELESCOPE
Until 31 July 2009
Monday to Friday – 14:00 (excluding 1, 16 & 22–26 June); Tuesday evening – 20:00 (& sky talk) (excluding 23 June); Saturday – 14:30; Sunday – 14:30; 16 June – 14:30
Built at a fraction of the normal cost – using a 91-segment mirror and an ingenious mobile



'tracker' – the Southern African Large Telescope has the largest aperture of any telescope in the world. Situated in the heart of the Karoo, from where the San people first developed their rich astronomical heritage, this telescope can see galaxies so distant that their light has taken many billions of years to reach us. It opens a new era for South African astronomy, and a new window on the cosmos.
Suitable for teenagers & adults
Planetarium Entrance Fees
Adults: R20,00; Children: R6,00; Adults (children's show only): R10,00; SA Pensioners & Students (with cards): R8,00
The Planetarium reserves the right to change or cancel advertised shows without prior notice.
The Iziko Planetarium is closed for maintenance on the first Monday of the month, excluding school holidays.

Art Karoo presents Another Starry Night: opening
23 June @ 19h00. Runs until 31 July.
Star inspired fine art …

Johannesburg Planetarium
Basic Astronomy – a series of four lectures
We are repeating our introduction to astronomy series on the following dates:
July: Tuesdays, starting 14 July
Sept: Mondays, starting 21 Sept
Venue: Jhb Planetarium, Wits University
Cost: R160pp for one 4-session series
More info: www.planetarium.co.za

Talks, outings and courses

Botanical Society of South Africa, Limpopo: Course: Workshop Fire management on the farm Bela Bela
Fred Farvard (DWAF – Working on Fire) and Frits van Oudtshoorn (Bushveld Eco Services) will be presenting a workshop in English and Afrikaans at the Klein Paradys Guest Farm. Topics covered will include veld fire legislation, safety, fire behaviour, firefighting strategies and techniques, construction of fire breaks and veld burning as a veld management tool. **Cost:** R500 per person (lunch and tea included). (**3 July 2009**)
Contact: For more information please contact Ilse van Oudtshoorn at bushveldec@lantic.net or 078 241 9178 or 014 717 3819 (mornings only).

Talk: Worms and waste
10h00, Haenertsburg Laurie Railton owner of Sanford Heights nursery will share his experiences with worm farming. Members free. Non-members R20. (**4 July 2009**)
Contact: Laurie on Cel 083-636-6026.

The Cape Bird Club
Zandvlei Nature Reserve. Meet at 09:00. Leader Bruce Mackenzie 021 531 1777. (**28 June 2009**)
Rondevlei. Meet at 08:00. Leader Ann Koeslag 021 762 5347 (**4 July 2009**)
West Coast Field Study Centre (Zoarvlei). Meet at 09:h30. Co-ordinator Helen Fenwick 021 785 1933. (**19 July 2009**)
Koeberg Nature Reserve. Meet at 09:00. Leaders Anne Gray 021 713 1231 and Frank Hallett 021 685 7465. (**23 July 2009**)
Rondevlei. Meet at 08:00. Leader Ann Koeslag 021 762 5347. (**1 August 2009**)
Helderberg Nature Reserve. Meet at 09:00. Co-ordinator Helen Fenwick, 021 785 1933. Leader Jill Mortimer. (**12 August 2009**)
Karoo National Botanic Gardens, *Worcester*. Co-ordinator Anne Gray, 021 713 1231. (**16 August 2009**)

Witwatersrand Bird Club
20 August, 2009. 'Energade' for nectar-feeding birds
An evening meeting with Cromwell Purchase. Cromwell has had a keen interest in birds and animals from a very young age. His studies include an MBChB at Wits University leading to his PhD in 2007- ongoing (avian physiology in nectar feeding birds). Cromwell will highlight aspects of his research, not going into too much scientific or technical detail, enlightening us as to the major physiological similarities and differences between African sunbirds and the honeyeaters of Australasia.
Venue: Delta Environmental Centre; 19:00–21:00

Diarise

- **The International Year of Biodiversity (2010).** In 2006 the United Nations declared 2010 to be the International Year of Biodiversity. It designated the secretariat of the Convention on Biological Diversity as the focal point for the year and invited the secretariat to cooperate with other relevant United Nations bodies, multilateral environmental agreements, international organisations and other stakeholders, with a view to bringing greater international attention to the continued loss of biodiversity. Look out for news of local events.
- **World Population Day, 11 July.** Theme: Investing in women is a smart choice. The theme of World Population Day this year is educating women as a way out of poverty. For more information go to: **http://www.unfpa.org/wpd/2009/en/**
- **International Day of the World's Indigenous People.** 9 August 2009. On 23 December 1994, the General Assembly [of the United Nations] decided that the International Day of the World's Indigenous People shall be observed on 9 August every year during the International Decade of the World's Indigenous People. For more information see: **http://www.un.org/events/indigenous/2008/index.shtml**

Why Ida is not the missing link

On 19 May this year, a 47-million-year-old fossil primate, popularly nicknamed Ida, was unveiled at the American Museum of Natural History in New York. Ida was hailed by the press as a 'missing link' in human evolution; Google incorporated an image of the fossil into its famous logo and the Mayor of New York, Michael Bloomberg, was invited to the unveiling. The media circus accompanying the release of Ida to the world instantly raised suspicions about the exact importance of the fossil and its place in our understanding of evolution.

Darwinius is a genus of Adaptiformes, a stem group of primates from the Eocene. It is the only know species of *Darwinius masillae* dated to 47-million years ago. Ida is the only known fossil. It was discovered in 1983 at the Messel pit, an old shale quarry that contains particularly well-preserved fossils, near Frankfurt in Germany. The fossil, divided into a slab and partial counterslab after the amateur excavation and sold separately, was not reassembled until 2007. The fossil is of a juvenile female, approximately 58 cm in overall length, with the head and body length excluding the tail being about 24 cm. It is estimated that Ida died at about 80 – 85% of her projected adult body and limb length.

The point about the adaptiforms is that their anatomy is similar to modern-day lemurs. So the question is what is her place in the family tree of humans and other primates? According to Chris Beard, the curator of vertebrate palaeontology at the Carnegie Museum of Natural History in Pittsburg, Pennsylvania, because Ida retains features found in all early primates she belongs somewhere closer to the base of the family tree of humans and other primates than living lemurs do. But, importantly, this does not make her a close relative of the anthropoids – the modern grouping that includes monkeys, apes and humans. As Beard says, she does not show anthropoid-like features that evolved *after* anthropoids split away from lemurs and other early primates. So she is *not* a 'missing link' in human evolution.

However, Ida is a remarkably complete specimen and will add significantly to the body of knowledge about some of the earliest and least human-like primates.

Source: New Scientist and Wikipedia

The main slab of the Darwinius masillae *holotype fossil.*

Image: Wikimedia commons

Stress does cause grey hair, but only as you age

Conventional wisdom has it that stress causes grey hair. Now we know that genotoxic stress *does* cause hair to whiten over time, according to a new study. Genotoxic stress can damage a cell's DNA. This new study may lead to new ways to treat grey hair, and more importantly, to treat serious conditions caused by genotoxic stress, such as cancer.

A strand of hair grows for several years, rests for two to three months and then dies and falls out. This process was linked by Emi Nishimura, a dermatologist in Japan, with the hair follicles' melanocyte stem cells. As a new hair grows, some melanocyte stem cells become melanocytes, giving the hair its colour, and others remain stem cells and store pigment for the next generation of hair. This process should carry on for life in theory, but, as we know, hair whitens with age – because these stem cells 'go missing'.

Nishimura had an idea that genotoxic stressors, such as radiation or harsh chemicals, may have something to do with this, because these stressors have been implicated in other signs of ageing. So she and her colleagues tested the idea in mice – who also go grey with age. The team exposed the mice to X-rays or chemotherapy drugs and noticed that the mice's melanocyte stem cells matured into colour-producing melanocytes, depleting the store of stem cells – the DNA-damaged cells effectively matured early.

'The mature cells lose their regeneration capabilities,' Nishimura explained. 'The mice then can't produce enough pigment-making cells' and consequently go grey. Moreover, the stressed mice's gray hairs and the cell populations in their follicles were indistinguishable from those of elderly mice, suggesting that genotoxic stress might drive natural greying as well.

However, these results do not support the idea that emotional stress causes grey hair – at least not yet.

Source: www.sciencenow.sciencemag.org

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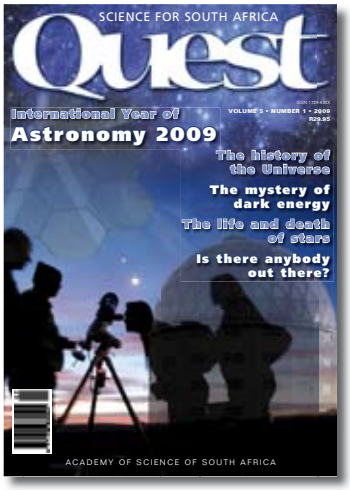

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SA astronomer: astronomy can foster development

Kevindran Govender, manager of the SALT Collateral Benefits Programme and South African chair for the International Year of Astronomy 2009, says that boosting astronomy in poor nations can help boost their development.

What relevance does a telescope and stargazing have to economic and social development? Not much, some would say. Actually a great deal, says Govender.

For instance, he says that the investment South Africa made in the Southern African Large Telescope boosted tourism, and hence jobs, in Sutherland, the small town that is home to SALT. In fact, from only a few hundred visitors a year, the town now sees more than 13 000 – that means more guesthouses, restaurants and other tourism-related businesses have sprung up. And the gains are not only local because about 60% of the components used in SALT were manufactured in South Africa, so more jobs have been created and skills gained.

Govender says that the same happened in Namibia, where the High Energy Stereoscopic System (HESS) was set up near Gamsberg Pass. The system comprises a number of telescopes that are used to investigate cosmic gamma rays. Some local farmers have set up small telescopes on their farms, and hire them out to amateur astronomers. Again, that means more people coming to the areas than in the past … more jobs, more opportunities.

Govender says that apart from the above-mentioned benefits, some components used in astronomy, such as the extremely fast switching devices built for the HESS project, can boost manufacturing and technology capacity.

Encouraging public engagement and interest in astronomy through promoting the science via education, tours, festivals, talks and suchlike will help build skills and jobs, and so help to boost a nation's social and economic development.

Source: SciDev.Net

Did dinosaurs survive the end-Cretaceous extinctions?

The Lost World was Sir Arthur Conan Doyle's account of an isolated community of dinosaurs that survived the catastrophic extinction event 65-million years ago. It is a work of fiction… or is it? New scientific evidence suggests that dinosaur bones from the Ojo Alamo Sandstone in the San Juan Basin, USA, date from after the extinction, and that dinosaurs may have survived in a remote area of what is now New Mexico and Colorado for up to half a million years after their fellow dinosaurs were becoming fossils. This controversial new research, published on April 28 in the journal *Palaeontologia Electronica*, is based on detailed chemical investigations of the dinosaur bones, and evidence for the age of the rocks in which they are found.

Jim Fassett, author of the research, says that after dinosaurs were killed or died of natural causes, their bodies were deposited in sands and muds, and 'it is possible for [their] bones to be exhumed by rivers and then incorporated into younger rocks.' This is not the usual way in which fossil deposits of this kind form, however, but it has been shown to explain some other post-extinction dinosaur bones and Fassett has amassed a range of evidence that indicates that these fossils from the Ojo Alamo Sandstone were not exhumed and redeposited, but that these dinosaurs really did live after the end-Cretaceous extinction event.

So does this provide conclusive proof that dinosaurs survived the Cretaceous extinctions? According to David Polly, one of the editors of the journal in which the research is published '… We already know that flying theropod dinosaurs (birds) and crocodiles survived, so the possibility of pockets of survivors of other types of dinosaur is not quite as farfetched as it might sound. Finding conclusive evidence, however, is a difficult matter when the crime scene is 65-million years old.' Polly says one thing is certain, however, and that is that if dinosaurs did survive, it was not for very long, and there were certainly far fewer of them.

Source: The Palaeontological Association via EurekAlert!

Large sponges can be reattached to coral reefs

Sponges are dominant components of coral reef ecosystems and are often more than a metre in diameter, and they may be hundreds or even thousands of years old. The trouble is, in order to survive they have to be attached to a reef, but if they are broken away, say by a storm, they cannot reattach themselves, and they die. Now scientists have come up with a novel way to reattach sponges… they have developed a sponge holder made of PVC piping anchored in a concrete block set on a plastic mesh base. The new method was tested on the Caribbean giant barrel sponge, *Xestospongia muta*. A number of these sponges were anchored in this way to reefs off Key Largo, Florida, and in depths of 15 m and 20 m, and 90% of the deep and 35% of the shallow transplants survived, with nearly 80% reattaching to the substratum and growing after 2.3 – 3 years.

Source: *Restoration Ecology*, via EurekAlert!

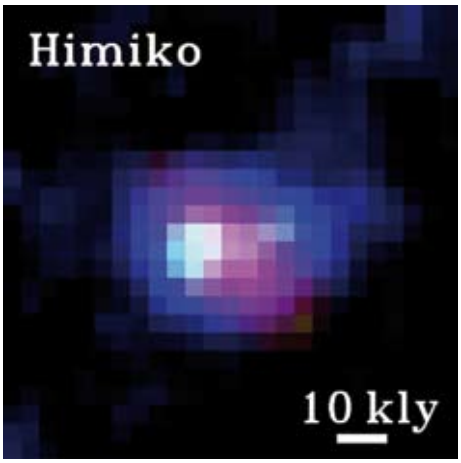
There's a mysterious blob in outer space!

Using information from a suite of telescopes, astronomers have discovered a mysterious, giant object that existed at a time when the universe was only about 800 million years old. Objects such as this one are dubbed extended Lyman-Alpha blobs. They are huge bodies of gas that may be precursors to galaxies. This blob was named Himiko after a legendary, mysterious Japanese queen – and it is huge! It stretches for 55 thousand light years*, a record for that early point in time. That length is comparable to the radius of the Milky Way's disk.

The researchers are puzzled by the object, however – even with superb data from the world's best telescopes, they are not sure what it is. It's so far away that scientists cannot learn about how it physically originated, or work out exactly what it is. It could be ionised gas powered by a super-massive black hole, a primordial galaxy with large gas accretion, a collision of two large young galaxies, super wind from intensive star formation, or a single giant galaxy with a large mass of about 40 billion suns. 'The farther out we look into space, the farther we go back in time,' explained lead author Masami Ouchi, a fellow at the Observatories of the Carnegie Institution who led an international team of astronomers from the US, Japan, and the UK. 'I am very surprised by this discovery. I have never imagined that such a large object could exist at this early stage of the universe's history'. At 55 thousand light years, Himiko is a big blob for that time.

**A light year is the distance light will travel in a year, and since it rockets along at 300 000 km a second, in a year light will travel 9.4605284×10^{12} – that works out at 9 460 730 472 580.8 km.*

Source: Carnegie Institution via EurekAlert!



This image of the Himiko object is a composite and in false colour. The thick horizontal bar at the lower right corner presents a size of 10 000 light years. This image is created by M. Ouchi et al., which is the reproduction of Figure 2 in the article of The Astrophysical Journal *May 2009 – 10 v696 issue.*

MIND-BOGGLING MATHS PUZZLE FOR *QUEST* READERS

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1. AM
2. BCDEK
3. FGJL
4. HI

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The solution is: 396 x 45=17 820