essential innovation introduced by ATRAP was the nested Penning trap[2], a clever device that solves the problem of how to confine oppositely charged positrons and antiprotons simultaneously. ATRAP came quite close to producing antihydrogen last year[3] but it is ATHENA that now reports success[1].

The antiprotons supplied to ATRAP and ATHENA from a particle accelerator move at almost the speed of light. First, this velocity must be reduced by an enormous factor, and during this process many particles are lost. The other constituents, the positrons, are emitted by a radioactive source and must also be slowed down to be useful. Having as many particles as possible to begin with is the key to success. The formation of an anti-atom in collisions between antiparticles is a rare event and, even when formed, most anti-atoms are not detected: about 130 antihydrogen atoms were observed in the ATHENA experiment, out of an estimated 50,000 produced.

Unfortunately, it is not yet possible to trap the anti-atoms. In fact, they reveal their presence only through their destruction in collisions with the apparatus walls (Fig. 1). An annihilating antiproton produces a number of energetic particles that fly off in various directions and these secondary particles leave directional traces in the detectors that surround the anti-atom sample. Like a ballistics expert on the scene of a crime who reconstructs the position of a gunman by tracing back trajectories from scattered bullet holes, the physicists are able to determine precisely the location of the antiproton annihilation.

It is then necessary to prove that the antiproton was not an isolated particle, but part of an antihydrogen atom. To show this, it is sufficient to find a positron that has also been annihilated at the same position and precisely the same time. The tell-tale signature of such a positron–electron annihilation in the wall material is the emission of two γ-ray particles of well-defined energy (512 keV each) that leave the 'scene of the crime' in exactly opposite directions.

The production of cold antihydrogen is a milestone, but it is just the beginning. Taking the next step towards trapping anti-atoms is fraught with difficulties. For one thing, the arrangement of magnetic fields needed to create a nested Penning trap is not optimal for trapping neutral anti-atoms. But the field is buzzing with ideas and ATHENA's progress will surely provide the motivation for researchers to face these challenges. ■

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Evolutionary biology

Death in the slow lane

Marcel Cardillo and Adrian Lister

Were the Late Pleistocene extinctions of large mammals the result of climate change or big-game hunting by humans? Reconstructing the biology of extinct species provides clues to the answer.

What caused the Late Pleistocene 'megafaunal' extinctions — the episode between about 50,000 and 10,000 years ago when mammoths, giant ground sloths, giant kangaroos (Fig. 1) and dozens of other large vertebrate species became extinct? The 'overkill' theory holds that human hunters drove the megafauna to extinction. An extreme form of the overkill theory is the 'blitzkrieg' model, in which the humans of Pleistocene times were big-game hunters, selectively and rapidly hunting the largest species to extinction as they swept through newly colonized continents. Others argue that the megafauna were killed off by climate and vegetation change at the end of the last ice age.

Usually, these theories are assessed by using the fossil record to compare the timing of megafaunal extinctions with human arrival on continents and climate change. But as he describes in a paper published in *Proceedings of the Royal Society*[1], Chris Johnson has taken a fresh approach by systematically comparing the traits of extinct mammal species with those that survived. He finds that it was not large size that predisposed species to extinction, but low reproductive rate. This does not fit in with the blitzkrieg view of events.

Johnson models the close relationship between body size and reproductive rate within taxonomic families of living mammals, and uses this to infer reproductive rates for extinct members of the same families. He cleverly uses a between-family comparison to sidestep the potential circularity of this method, and then shows that the likelihood of extinction was higher for groups with lower reproductive rates, regardless of their body size. Even relatively small mammals became extinct if their fecundity was low enough. Strikingly, the threshold reproductive rate at which the chance of extinction exceeds 50% is roughly the same — about one offspring per female per year — for all groups examined, from 700-gram lemurs to one-tonne cattle. It seems that what was lost during the Pleistocene was not so much the megafauna as the 'bradyfauna' — a whole way of life based on slow life-history.

These results run counter to the idea of extinction by rapid blitzkrieg because, if larger mammals were being selectively hunted, body size as well as reproductive rate should be an important determinant of extinction. However, Johnson noticed another interesting pattern in his data. Those mammal species that bucked the trend, surviving to the present day despite low reproductive rates, tend to be arboreal, nocturnal or inhabitants of dense forests, high latitudes or high altitudes — all of which ought to protect them from human hunters. Johnson interprets this as evidence in favour of more general overkill, where species of all body sizes were harvested.

Johnson's findings complement those of Alroy[2], who modelled the effects of human hunting on Late Pleistocene extinctions in North America. Without assuming human preference for big game, Alroy's model matched the observed pattern of large-mammal extinction. The two studies agree that even low levels of hunting could have led to extinction: Johnson suggests that, because of the slow reproductive rates of the victims, extinctions need not have occurred rapidly, while Alroy gives a median extinction date in North America of about 900 years after the Clovis hunter–gatherers migrated into the continent from Asia about 13,400 years ago. Whether or not this can be considered rapid blitzkrieg is a matter of perspective — ecologists and palaeontologists are used to working at very different timescales.

Johnson's result leaves the effects of climate change an open question. Species with slow reproductive rates would have been the most vulnerable to environmental degradation as well as to hunting. For Australia, it has been suggested that during the Last Glacial Maximum (around 20,000 years ago), expansion of the arid interior at the expense of the lush coastal zone was a causal factor in Pleistocene extinctions. The finding that, even in Australia, survivors tended to live in forest or other cryptic habitats, could be interpreted as evidence against this climate model. Moreover, some dates for Australian fossil sites[3,4] place megafaunal extinctions well before the Last Glacial Maximum, at around the time of the first evidence of humans.

Perhaps a similar approach to Johnson's could be used to test predictions of the climate hypothesis — comparing, say, extinction patterns in Australian taxa such as reptiles and mammals that differ in their ability to cope with extreme drought. Further, the climatic models for other continents are very different and need to be tested separately. The disappearance of the

MICHAEL LONG/NHMPL

Figure 1 **Prehistoric victim. A reconstruction of *Procoptodon*, a giant short-faced kangaroo from the Late Pleistocene of Australia, which stood about 3 m high.**

steppe–tundra and other mixed vegetational environments in the northern continents, to be replaced by zoned forest, has been implicated in extinctions of mammoth, woolly rhino and other species there[5]. Here, the patterns of survival may fit climate/vegetational models at least as well as those invoking overkill.

The Pleistocene extinctions did not touch all regions of the world. In southern Asia, and especially Africa, the megafauna survived largely intact through the Pleistocene to the present. Africa was excluded from Johnson's study, but why did it suffer so few extinctions? Overkill theorists claim that, because humans originated there, African mammals coevolved with people and were thus less 'naive' to human predation. Climate theorists, on the other hand, propose that the array of African vegetation types was modified relatively little by Pleistocene climate change, allowing the survival of even the largest mammals (elephants, rhinos, and so on). Johnson's approach, centred on taxonomic groups, points to a different line of enquiry. Could it be that African mammals, several groups of which are believed to be related and which are collectively known as the Afrotheria[6], tend to have faster life-history relative to body size than mammals of other continents?

We can draw parallels with the current extinction crisis from Johnson's findings. Alroy points out that the modelled rates of Late Pleistocene extinction were too slow to be perceived by the humans of the time. Today's extinctions have accelerated to an observable pace. Moreover, slow life-history is a strong predictor of current extinction risk in living mammals[7]. Perhaps in another 50,000 years — or even sooner — we will be left only with those that live life in the fast lane. ■

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100 YEARS AGO

So much has been written of late on totemism that I feel some diffidence in burdening still further the literature of the subject. But I may plead a slight claim on your attention, as I happen to be an unworthy member of the Crocodile kin of the Western tribe of Torres Straits, and I have been recognised as such in another island than the one where I changed names with Maino, the chief of Tutu, and thereby became a member of his kin. … What is most needed at the present time is fresh investigation in the field. Those who are familiar with the literature of the subject are only too well aware of the imperfection of the available records. There are several reasons which account for this. Some of the customs and beliefs associated with totemism have a sacred significance, and the average savage is too reverent to speak lightly of what touches him so deeply. Natives cannot explain their mysteries any more than the adherents of more civilised religions can explain theirs. Further, they particularly dislike the unsympathetic attitude of most inquirers, and nothing shuts up a native more effectually than the fear of ridicule.
From *Nature* 2 October 1902.

50 YEARS AGO

The attitude of the general science graduate to experiments involving subjective judgments is curious and illogical, even if understandable. He is taught throughout his study period to believe that those things which he measures during the course of his 'practical work' are facts, inviolable and true. ... Above all, he believes in the dogma of Kelvin, that we must measure to be able to understand. He rarely succeeds in grasping the principles of uncertainty in physical measurement, and many years may pass before he realizes that all measurement demands a judgment on the compromise between accuracy and expediency. As a result, he dismisses all experiments which involve direct subjective judgements as being 'vague and inaccurate'. This dogmatic attitude is not confined to the young graduate. It finds its way into higher levels, where great efforts are made to develop physical analogues to supplant the human observer in a perceptual situation. Consequently, it happens that the experimenter who uses human subjects as indicators finds it necessary to go to unusual lengths to explain his means as well as his ends.
From *Nature* 4 October 1952.