Hominid revelations from Chad

Bernard Wood

The story of human origins in Africa takes a twist with the description of a 6–7-million-year-old cranium from Chad. The discovery hints at the likely diversity of early hominids.

A single fossil can fundamentally change the way we reconstruct the tree of life. More than 75 years ago, Raymond Dart's description[1] of the Taung skull from southern Africa wrought such a transformation with regard to human evolution. Dart provided hard evidence to support Darwin's prediction that the roots of human evolutionary history run deepest in Africa.

A fossil cranium (Fig. 1), discovered by Michel Brunet and his colleagues and described in this issue, marks a similar turning point in our understanding of human origins. Discussion of the cranium and associated fossils is on page 145 (Brunet *et al.*[2]), with presentation of the contextual evidence (Vignaud *et al.*[3]) on page 152. The fossils — the cranium, a jaw fragment and several teeth — belong to a primitive human precursor, or hominid, that is an astonishing 6–7 million years old. The transformation wrought here is more nuanced than Dart's, but it is as fundamental. Here we have compelling evidence that our own origins are as complex and as difficult to trace as those of any other group of organisms.

For almost 150 years[4] it has been suggested that modern humans are more closely related to the African apes than they are to the orang-utan. Nowadays, evidence from both bones and teeth[5–7], and soft tissues (muscles, nerves, and so on)[8], and from molecular and DNA analyses[9,10], support the view that modern humans and chimpanzees are particularly closely linked. When the DNA differences are calibrated by using palaeontological evidence, they indicate that the hypothetical ancestor of modern humans and the chimpanzee lived between about 5 and 7 million years ago.

The hominid fossil record outside Africa has stubbornly failed to break the 2-million-year barrier. Thus, if the 'molecular clock' keeps reasonably good time, between 3 and 5 million years or so of our independent evolution took place on the African continent. Four regional 'windows' provide fossil evidence relevant to our early evolutionary history. The southern African window was revealed by Dart in 1925 when the first (and only) hominid fossil from Taung, near Kimberley, was recognized; since then, neighbouring cave sites have provided a rich fossil record that stretches back to around 3–3.5 million years ago[11]. The East African window comprises sites along the Eastern, or Gregory, Rift Valley, from close to the Gulf of Aden

Figure 1 **The cranium of the newly described *Sahelanthropus tchadensis* and (below) the opening page of Raymond Dart's 1925 description of the Taung skull.**

in the north to northern Tanzania in the south. The sites are associated with sedimentary basins or the rivers that fed or drained them. Two of them, Middle Awash in Ethiopia[12,13] and Lukeino in Kenya[14], have so far provided the oldest evidence of creatures that are plausible human ancestors.

The two remaining regions, Malawi and Chad, were, until now, more like spy-holes than windows. Malawi has provided evidence of one of the large-toothed hominid species, probably *Paranthropus aethiopicus* (see Fig. 2, overleaf). The first 'early hominid' from Chad, *Tchadanthropus uxoris*, found in 1961, turned out to be the face of a modern human skull that had been so eroded by wind-blown sand that it mimicked the appearance of an australopith, a primitive type of hominid. The second Chad hominid, *Australopithecus bahrelghazali*, discovered[15] at a site called Koro Toro in 1995, is an authentic australopith and alerted palaeontologists to the potential of central West Africa.

Four areas in and around the Chad basin have yielded mammalian fossils, but it is one locality, TM 266, in the oldest of these areas — Toros-Menalla in the Djurab Desert — that provided Brunet's team with the fossils they describe in this issue. The discovery is a tribute to the tenacity of Brunet, Vignaud and their scientific colleagues, and to their intrepid local field team. The sand-laden wind

blows incessantly and the fossil layers are difficult to detect: they are at most a few metres thick and a far cry from the banks of sediment that we are used to seeing in pictures of Olduvai Gorge in Tanzania, and the like. Yet, despite the harsh present-day environment, the vertebrate fossils are well preserved, and the hominid cranium (designated TM 266-01-060-1) is remarkably complete.

Absolute — isotope-based — dating methods cannot be applied to the fossil layers at Toros-Menalla because there are no ash layers to provide the necessary argon and

potassium. Nor are the sediments suitable for magnetism-based dating methods. Instead, the team matched the rich vertebrate fossil record at TM 266, consisting of examples of 44 different groups, with the equivalent record from sites in East Africa that have absolute dates. The best matches are with two sites in Kenya: the Lukeino Formation of the Tugen Hills (which dates to about 6 million years ago) and the Nawata Formation at Lothagam (5.3–7.4 million years). The upshot is a reliable age estimate of about 6–7 million years for the Toros-Menalla fossils.

The researchers compared their new evidence with what has been published about two other claimants for the title of 'earliest hominid', *Ardipithecus ramidus* from the Middle Awash[12,13] and *Orrorin tugenensis* from Lukeino[14]. They satisfied themselves (and others, myself included) that the teeth of the new fossils are taxonomically distinctive, and accordingly assigned the fossils to a new species and genus, *Sahelanthropus tchadensis*.

What was the role of *S. tchadensis* in the evolution of chimpanzees and modern humans? The latter two look very different, but the differences between the earliest ancestors of chimpanzees and modern humans are likely to have been more subtle. The conventional presumption is that the human–chimp common ancestor, and the earliest members of the chimp lineage, or clade, would have been adapted for life in the trees, with the trunk held either horizontal or upright and with the forelimbs adapted for knuckle-walking on large branches or on the ground. This would have been combined with projecting faces that accommodated elongated jaws bearing relatively small chewing teeth and, in males, large upper canine teeth that would have worn against the lower premolars.

Early hominids at the base of our own clade, in contrast, would have been distinguished by at least some skeletal and other adaptations for an upright posture and bipedal walking and running, linked with a chewing apparatus that combined proportionally larger chewing teeth, modest-sized male canines that wore only at the tip of the crown, and some evidence of an increase in brain size. Against these criteria it is the face, jaw and canines of *S. tchadensis* that point to its being a hominid, at (or at least close to) the base of the modern human clade.

There are two current hypotheses about human origins and the early stages of hominid evolution. According to the linear, or 'tidy', model[16], the distinctive hominid anatomy evolved only once, and was followed by a ladder-like ancestor–descendant series. In this model there is no branching (cladogenesis) until well after 3 million years ago. The bushy, or 'untidy', model sees hominid evolution as a series of successive adaptive radiations — evolutionary diversi-
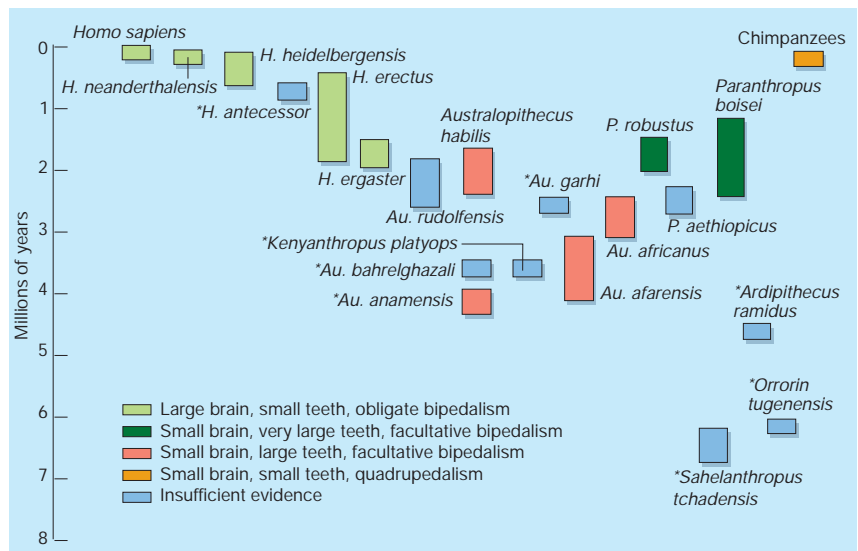

Figure 2 **The known fossil record of hominids, including *S. tchadensis*[2,3], also showing ourselves (top left) and the chimpanzee (top right). Extinct species are indicated with the dates of the earliest and latest fossil evidence, but these are likely to increase and decrease, respectively, especially for the less well-known examples. Species are assigned to one of four categories, based on brain and cheek-tooth size, and inferred posture and locomotion (we are obligately bipedal; facultative bipedalism is the ability to walk or run on two legs, or as a quadruped, according to circumstances). A fifth category is for 'insufficient evidence'. The species marked with an asterisk were all unknown a decade or so ago, an indication of the paucity of evidence, until recently, of hominid evolution between 1 and 4 million years ago. This comparatively rich record contrasts with the earlier part of the hominid fossil record. There are likely to be many 'undiscovered' species in the fossil record between 7 and 4 million years ago, and in reconstructing the early stages of human evolution in particular the incompleteness of data should always be acknowledged.**

fication in response to new or changed circumstances — in which anatomical features are 'mixed and matched' in ways that we are only beginning to comprehend[17,18]. This model, to which I subscribe, predicts that because of the independent acquisition of similar shared characters (homoplasy), key hominid adaptations such as bipedalism, manual dexterity and a large brain are likely to have evolved more than once[19]. So the evidence of one, or even a few, of the presumed distinguishing features of hominids might not be enough to link a new species with later hominids, let alone to identify it as the direct ancestor of modern humans.

What is remarkable about the chimp-sized cranium TM 266-01-060-1 discovered by Brunet *et al.* is its mosaic nature. Put simply, from the back it looks like a chimpanzee, whereas from the front it could pass for a 1.75-million-year-old advanced australopith. The hominid features involve the structure of the face, and the small, apically worn, canine crowns. Other hominid features are found in the base of the cranium and in the separate jaw fragment. If we accept these as sufficient evidence to classify *S. tchadensis* as a hominid at the base, or stem, of the modern human clade, then it plays havoc with the tidy model of human origins. Quite simply, a hominid of this age should only just be beginning to show signs of being a hominid. It certainly should not have the face of a

hominid less than one-third of its geological age. Also, if it is accepted as a stem hominid, under the tidy model the principle of parsimony dictates that all creatures with more primitive faces (and that is a very long list) would, perforce, have to be excluded from the ancestry of modern humans.

In contrast, the untidy model would predict that at 6–7 million years ago we are likely to find evidence of creatures with hitherto unknown combinations of hominid, chimp and even novel features. Moreover, because it acknowledges substantial amounts of homoplasy, the model would further predict that certain structures — such as substantial brow ridges (which *S. tchadensis* has, as is evident in Fig. 1) — are likely to be unreliable for reconstructing relationships because creatures can share features such as brow ridges without necessarily inheriting them from a common ancestor[20]. *S. tchadensis* is a candidate for the stem hominid, but in my view it will be impossible to prove that it is.

My prediction is that *S. tchadensis* is just the tip of an iceberg of taxonomic diversity during hominid evolution 5–7 million years ago. Its potentially close relationship with our own, hominid, twig of the tree of life is surely important. More notably, however, I think it will prove to be telling evidence of the adaptive radiation of fossil ape-like creatures that included the common ancestor of modern humans and chimpanzees. The fauna of the

Burgess Shale in Canada, which samples a bewildering array of invertebrate groups some 500 million years ago, is a famous example of diversity at the base of an adaptive radiation. Does *S. tchadensis* belong to the African-ape equivalent of the Burgess Shale?   ■

Bernard Wood is in the Department of Anthropology, The George Washington University, 2110 G Street NW, Washington DC 20052, USA.
e-mail: bwood@gwu.edu

1. Dart, R. A. *Nature* **115**, 195–199 (1925).
2. Brunet, M. *et al. Nature* **418**, 145–151 (2002).
3. Vignaud, P. *et al. Nature* **418**, 152–155 (2002).
4. Huxley, T. H. *Evidence as to Man's Place in Nature* (Williams & Norgate, London & Edinburgh, 1863).
5. Groves, C. P. in *Systematics of the Great Apes* (eds Swindler, D. R. & Erwin, J.) 187–217 (Liss, New York, 1986).
6. Groves, C. P. & Paterson, J. D. *J. Hum. Evol.* **20**, 167–183 (1991).
7. Shoshani, J., Groves, C. P., Simons, E. L. & Gunnell, G. F. *Mol. Phylogenet. Evol.* **5**, 101–153 (1996).
8. Gibbs, S., Collard, M. & Wood, B. *J. Anat.* **200**, 3–49 (2002).
9. Gagneux, P. V. & Varki, A. *Mol. Phylogenet. Evol.* **18**, 2–13 (2002).
10. Wildman, D., Grossman, L. I. & Goodman, M. in *Probing Human Origins* (eds Goodman, M. & Moffat, A. S.) 1–10 (Am. Acad. Arts Sci., Cambridge, MA, 2002).
11. Partridge, T. C., Shaw, J., Heslop, D. & Clarke, R. J. *J. Quat. Sci.* **14**, 293–298 (1999).
12. White, T. D., Suwa, G. & Asfaw, B. *Nature* **371**, 306–312 (1994).
13. Haile-Selassie, Y. *Nature* **412**, 178–181 (2001).
14. Senut, B. *et al. C. R. Acad. Sci. Paris, Earth Planet. Sci.* **332**, 137–144 (2001).
15. Brunet, M. *et al. Nature* **378**, 273–275 (1995).
16. Asfaw, B. *et al. Science* **284**, 629–635 (1999).
17. Wood, B. R. & Richmond, B. G. *J. Anat.* **197**, 19–60 (2000).
18. Leakey, M. G. *et al. Nature* **410**, 433–440 (2001).
19. Collard, M. C. & Wood, B. A. *Proc. Natl Acad. Sci. USA* **97**, 5003–5006 (2000).
20. Lieberman, D. E. in *Development, Growth and Evolution: Implications for the Study of the Hominid Skeleton* (eds O'Higgins, P. & Cohn, M. J.) 85–122 (Academic, London, 2000).

Planetary science

Out on the edge

William B. McKinnon

The Kuiper Belt, beyond Neptune, is the third great domain of the Solar System, and home to the Pluto–Charon binary. What are the prospects for exploration of these distant worlds?

The discovery of the Kuiper Belt in the far regions of the Solar System is one of the great achievements of the space age. In addition to the small planet Pluto and its large moon Charon, the belt contains about 100,000 worlds greater than 100 km in diameter, as well as a vast number of smaller, cometary bodies[1]. Unlike the domains of the terrestrial planets (Mercury to Mars) or the gas giants (Jupiter to Neptune), the Kuiper Belt has never been explored by spacecraft — although one mission, 'New Horizons', has been competitively selected and is in its final design phase[2]. In May, a workshop* was convened to review progress since the last major conference on Pluto–Charon[3] and to imagine the results of the possible spacecraft encounter in 2015 or 2016.

In astronomy, there is no substitute for resolution and Pluto and Charon are, to put it mildly, poorly resolved from Earth. One clear signature, however, is Pluto's rotational lightcurve — the variation of the planet's apparent brightness with time. Pluto's lightcurve is quite pronounced, both in terms of brightness and spectral features, and implies at least three separate types of surface terrain (W. Grundy, Lowell Observatory, Arizona): a bright, nitrogen-ice-rich terrain containing dissolved methane and carbon monoxide; another bright, reddish terrain dominated by methane ice; and a third dark, volatile-depleted terrain betraying only the slightest hint of the broad infrared absorp-

tions of water ice[4,5]. Such a complex, variegated surface goes a long way towards explaining the peculiarities of Pluto's heat signature: the

Figure 1 **Defrosting Pluto. This diagram shows how volatile substances migrate across the varying terrain of Pluto's surface, and a possible internal structure for the 2,400-km-diameter planet. Frost on the sunlit hemisphere sublimes to form a vaporous atmosphere, some of which escapes but most of which flows to the dark hemisphere and condenses. The hypothesized internal structure is based on what is known about Pluto's composition and a plausible thermal history. An internal ocean is possible, though not guaranteed, as is a layer of heavy organic compounds (not shown) beneath the ocean. (Modified from a figure by J. Spencer, Lowell Observatory.)**

planet simultaneously exhibits a nitrogen-dominated atmosphere in vapour-pressure equilibrium with nitrogen-frosted terrain at a temperature of 40 K, and warmer regions where volatile ices have burned off[6]. In this regard, Pluto is Mars-like in its surface–atmosphere interaction.

The lightcurve data only hint at the complexity of Pluto's surface. A higher-resolution map — derived from the mutual eclipses and transits of Pluto and its moon in the 1980s — shows that even within the dark, volatile-depleted regions there exist significant visual colour differences[7], although these differences are not as extreme as those seen in the Kuiper Belt population as a whole (S. Tegler, Northern Arizona Univ.).

By contrast, Pluto's Neptune-orbiting cousin, Triton, exhibits only a modest visible lightcurve, a clear spectral signature of water ice, and no extensive dark regions. Yet Triton is hardly a dull or static satellite. Triton's lightcurve has recently increased in amplitude (B. Buratti, NASA Jet Propulsion Laboratory, California), its spectrum has reddened distinctly more than once, and even its atmospheric pressure has been increasing (J. Elliot, Massachusetts Institute of Technology)[8], so there is great interest in monitoring Pluto for similar effects. As a consequence of Pluto's eccentric orbit about the Sun and the large tilt of its rot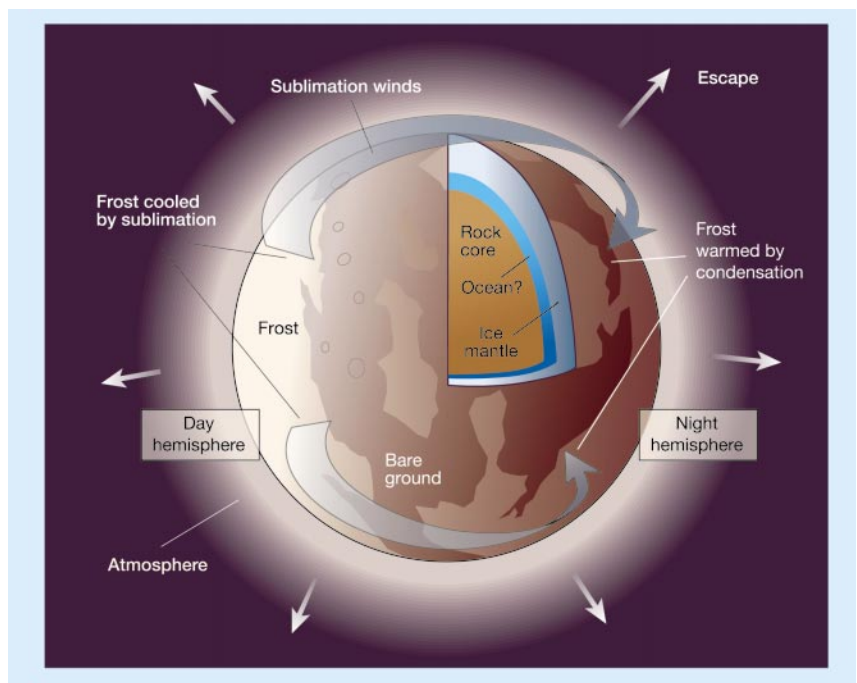ation axis, Pluto's surface is variably illuminated, and