By their teeth ye shall know them

An argument about a fossil suggests that the decade-old lessons of cladistics have not yet been fully appreciated.

IF ever there was a good story in palaeontology, it is the one about the gradual evolution of mammals from reptiles. Some 280 million years ago, a reptile appeared that resembled mammals in certain key features: it was the earliest-known therapsid (M. Laurin & R. R. Reisz, *Nature* **345**, 249–250; 1990). Over the next 80 million years, characteristically mammalian features appeared among therapsids. In particular, the dentary (tooth-bearing) bone of the jaw began to predominate over the other jaw elements. Some of the later therapsids were astonishingly mammal-like in form.

In the Triassic Period, around 200 million years ago, the earliest 'true' mammals appeared. But the line between mammals and therapsids was by then so fine as to be barely discernible. The first mammals lived alongside the therapsids, which finally became extinct in the Jurassic around 160 million years ago.

Earlier this, year, Fox *et al.* described the fragmentary dentary and teeth of what they claimed to be a therapsid (*Nature* **358**, 233–235; 1992). The presence of small, post-dentary bones is suggested by scars in the inner face of the bone. The teeth have elaborate cusps, but single, unbranched roots.

Fox *et al.* named this fossil *Chronoperates paradoxus,* an 'unexpected wanderer in time', because it lived in the Palaeocene, 100 million years after the last known therapsids were thought to have died out. Such a discovery was unexpected indeed.

Aware of the implications, Fox *et al.* discussed what, if anything, *Chronoperates* could be, if not a therapsid. The most likely alternative is a symmetrodont, a member of an extinct group of Mesozoic mammals. But although symmetrodonts have multi-cusped teeth, the roots of the lower cheek teeth have two roots apiece, not just one, and there are a number of other differences in detail. These differences, though, are 'subtle', as M. Novacek pointed out in the accompanying News and Views article (*Nature* **358**, 192; 1992).

H.-D. Sues went further, to dispute all the characters proposed by Fox *et al.* as indicative of therapsid affinity (*Nature* **359**, 278; 1992). Some therapsids have teeth with roots that are "incipiently divided", weakening the equation of single roots with the therapsid state, and the scars for the post-dentary bones in *Chronoperates* are open to other interpretations (including post-depositional distortion.) Nevertheless, Sues stops short of suggesting what he thinks *Chronoperates* actually is, if not a therapsid — something seized on by Fox *et al.* in their reply on page 540 of this issue. The debate is likely to run and run, at least until more complete remains of this intriguing creature are unearthed.

But there is a deeper problem: that *Chronoperates* is a fossil out of time only if one assumes that the transformation series between reptiles and mammals happened in the way the textbooks would have us believe. It could be that the distinction between mammals and therapsids rests with the beholder: what with the capacity of the human mind to pick patterns from apparently random information, the transformation series between reptiles and mammals is just too good to miss.

Transformation series like this do not really work, because, unlike us, evolution has not the benefits of hindsight. In other words, transformation series 'create' evolutionary lineages after the fact. Consider: if the mammals (and *Chronoperates*) had vanished in the Palaeocene, would the transition between therapsids and mammals in the fossil record be so obvious? Would we not see, instead, a bush of competing, convergent lineages in which the features we now see as mammalian (thanks only to the abundance of modern mammals) appear more randomly? If so, then the line between therapsid and mammal, so long debated, would be seen as artefactual, and it would hardly matter whether *Chronoperates* is one thing or the other.

In the real world, of course, the mammals did evolve and diversify, but the very fact of their existence implies an ancestry in which the characteristic features of mammals appeared. It is no surprise, then, that these features can be recovered from fossils: it is easy to find such things, when one is convinced of the appearance of that for which one seeks.

Because of the recursion that crops up whenever tranformation series are invoked, to so-called school of 'transformed cladists' suggested that the only objective way to reconstruct phylogeny is with information from extant species (D. Rosen *et al., Bull. Am. Mus. nat. Hist.* **167**, 163–275; 1981). This means that proposed transformation series can only be tested against phylogenies created with independent neontological or ontogenetic information. If fossils are to be included at all, they must be fitted in afterwards, as provisional groups called 'plesions' (C. Patterson & D. Rosen, *Bull. Am. Mus. nat. Hist.* **158**, 85–172; 1977). Above all, information from fossils cannot be used to overturn a phylogeny created using neontological data — not because they are unable to do so, but because such a course would be methodologically unsound. Based on these ideas, B. G. Gardiner proposed that of all the amniotes, mammals were most closely related to birds (*Zool. J. Linn. Soc.* **74**, 297–232; 1982). This idea was generally pilloried, and contested in print by a student of therapsids (T. S. Kemp, *Zool. J. Linn. Soc.* **92**, 67–104; 1988).

Moreover, J. Gauthier *et al.* used an extensive database to show that fossils could be used to overturn phylogenies based on neontological data, irrespective of whether it was right to do so (*Cladistics* **4**, 104–209, 1988: H. Gee, Nature **334**, 13–14; 1988.) The process turned a phylogeny of amniotes that owed much to Gardiner, into the more traditional scheme complete with the reptile-to-mammal transition. But when the analysis was repeated using taxa that were present only up to and including the Triassic — before the modern radiations of mammals — the transformation series was less apparent.

There is an illuminating literary parallel to all this. In his essay "Kafka and his Precursors", Jorge Luis Borges speculates on the diverse sources which could conceivably have influenced Kafka's own writing. "In each of these texts", he writes, "we find Kafka's idiosyncrasy to a greater or lesser degree, but if Kafka had never written a line, we would not perceive this quality; in other words, it would not exist .... The fact is that every writer *creates* his own precursors." (Original emphasis: translation by J. E. Irby).

It is Spike Milligan, though, who perhaps summarizes the debate about *Chronoperates* most succinctly, when recounting the reaction of tourists confronted by the eponymous hero of his childrens' story *The Bald Twit Lion:* "The tourists couldn't believe their eyes, some couldn't even believe their teeth". **Henry Gee**