

cal evidence has it), then the aquatic adaptations of hippos and living cetaceans must be convergences that occurred well after the split of their respective lineages. This is because certain primitive cetaceans (paki-cetids) have many ear⁴ and ankle⁶ structures typical of a land mammal, and mesonychids were fully terrestrial and adapted to running (Fig. 1a).

What about the relative strengths of the two lines of evidence? Morphological studies of ungulate–cetacean phylogeny take in a much wider range of taxa than the molecular studies. This is because the living artiodactyls and cetaceans available for molecular analyses represent only a few twigs of their bushy family trees that have survived pruning by extinction. As O'Leary and Geisler¹ point out, 90% of ungulate genera and more than 86% of the cetacean genera are extinct. Taking the mesonychid and cetacean fossil taxa into account produces a markedly different evolutionary history (Fig. 1a). From this, O'Leary and Geisler conclude that artiodactyls are a clade to the exclusion of cetaceans. Here we have a good example of the principle that including data from early divergent fossil lineages can shake, and reshape, the trees of living taxa based solely on molecular evidence.

However, for living taxa, use of sequences of genes and proteins is in some ways more powerful than use of morphological

characters. In recent years, more genes in larger sequence samples have been added to the arsenal for estimating ungulate and cetacean phylogeny^{9–12}. And the poor taxonomic sampling of some of the earlier molecular work has at least in part been redressed¹⁰. All in all, because molecular characters can vastly outnumber morphological features, they often prevail in simultaneous analyses of conflicting data sets. That is, in such analyses they effectively swamp the morphological estimates of ungulate–cetacean phylogeny.

Both morphological and molecular data are vulnerable to the problem of homoplasies — reversals to ancestral conditions or parallel changes in different lineages that can camouflage the true phylogeny. In this sense, neither approach is better than the other. For instance, the ear region of the skull, traditionally considered to be a good source of highly stable characters, shows some glaring homoplasies among the ungulates and cetaceans^{4,5}. Moreover, the fossil record of many early divergent fossil taxa is incomplete, resulting in ambiguities in morphological estimates.

On the molecular side, DNA and protein sequences have parallel and back mutations. Even the newest studies using retroposons, which are the RNA-mediated insertion sequences interspersed in the genome, have their limitations. Retroposons show a low

level of homoplasy^{12,13}, but mutational decay of the flanking region of retroposons may make them difficult to detect in older lineages. This means that retroposon-based estimates may not be effective for resolving lineages that go back more than 50 million years¹⁴. Cetaceans were already diversified by 53.5 million years ago, and their divergence from extant artiodactyls goes back much further^{15,16} than that.

A way to untie this Gordian knot may be to seek out compatible aspects of the molecular and morphological data sets. Measurement of the hidden support and conflict between them¹⁰ can help extract additional information. Also, morphological features should be better analysed for some living taxa for which extensive molecular data are available. Such studies may be just as helpful as discoveries of new fossils and genes in resolving details of the cetaceans' phylogenetic tree — most particularly, the question of which group is their sister taxon. ■

Zhexi Luo is in the Section of Vertebrate Paleontology, Carnegie Museum of Natural History, Pittsburgh, Pennsylvania 15213, USA.
e-mail: luoz@carnegiemuseums.org

1. O'Leary, M. A. & Geisler, J. H. *Syst. Biol.* **48**, 455–490 (1999).
2. O'Leary, M. A. *Cladistics* **15**, 315–330 (1999).
3. Van Valen, L. M. *Bull. Am. Mus. Nat. Hist.* **132**, 1–126 (1966).
4. Luo, Z. & Gingerich, P. D. *Papers on Paleontology (Univ. Michigan)* **31**, 1–98 (1999).
5. Geisler, J. H. & Luo, Z. in *Evolutionary Emergence of Whales* (ed. Thewissen, J. G. M.) 161–212 (Plenum, New York, 1998).

Fibre optics

Transparent talk

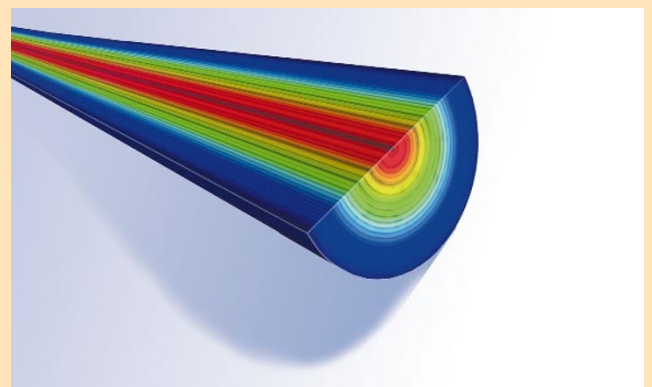
Modern telecommunications rely on the transmission of light signals along fibre-optic cables — fast, but how to minimize signal degradation over large distances? The secret is to eliminate contaminants that cause unwanted absorption. These intruders tend to creep into the fibres during the manufacturing stages. Elsewhere in this issue (*Nature* **404**, 262–264; 2000), Gordon Thomas and colleagues reveal how the main culprit, water, sneaks in. Putting this knowledge into practice allows the manufacture of dry fibres with near maximal transparency and improved bandwidth.

The problem with water, in particular the hydroxyl (OH) group, is that it gets excited when irradiated by certain infrared wavelengths. As this band is used for telecommunications, precious signal power can be lost in vibration of the water molecules.

So where does the water come from? One process for making

optical fibres involves heating silica rods with ultra-pure glass cores to very high temperatures. Once softened, the rods can be drawn out into fibres some tens of kilometres long. To achieve the necessary temperatures — in excess of 2,000 °C — it is common to use torches that burn hydrogen and oxygen: the perfect recipe for water.

But the incorporation of water into the silica rods is a more subtle matter. To investigate this process, Thomas and colleagues measured the transmission of infrared light through a small section of rod that had been cooled before drawing out, thereby 'freezing in' the water. They found that the absorption, and hence the hydroxyl concentration, is much stronger in the outer layers of the rod. This can be seen in the figure, which indicates the varying hydroxyl concentrations through a cross-section of the rod. (The colour scale is logarithmic, blue representing the highest concentrations.) Clearly, the water



diffuses from the outside in.

Given that the signals in optical fibres are confined to a narrow core region, the distribution of water in the rod might appear to be good news. But Thomas and colleagues found that the drawing process — which increases the aspect ratio by a factor of about a hundred million — lets the water in much further. They confirmed this by calculating the diffusion coefficient, a quantity that describes the flow of both water and glass during the contamination

process. This parameter was much higher than expected from low-temperature diffusion, probably reflecting an increased mobility of hydroxyl groups in the hot, molten state.

There is no doubt that absorption by hydroxyl groups contributes significantly to transparency loss in optical fibres. Uncovering the physical origin of the contamination points to an obvious solution: pick a water-free heat source. **Karen Southwell**