in type III collagen. All such diseases could, in principle, be investigated using the authors' approach.

The techniques used by Gauba and Hartgerink, based on circular dichroism spectroscopy, do not provide high-resolution structural information. But other self-assembling homotrimer triple-helical peptides have proved amenable to molecular-level studies by nuclear magnetic resonance and X-ray crystallography[1,11]. It will therefore be exciting to see whether these self-assembling heterotrimeric peptides[2] can be used to directly visualize the structural perturbation in a collagen disease and provide a basis for rational design of therapeutic drugs. These more realistic peptide models of collagen could also reveal how mutations affect the formation of higher-order structures and interactions with the other components of bone. ■

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EVOLUTIONARY BIOLOGY

The amphioxus unleashed

Henry Gee

The genome sequence of a species of amphioxus, an iconic organism in the history of evolutionary biology, opens up a fresh vista on the comparative investigation of chordates and vertebrates.

One might be forgiven for never having heard of the amphioxus, a small, vaguely fish-shaped creature (Fig. 1), which spends most of its life buried in sand filtering detritus from seawater. Yet for many decades, beginning in the mid-1800s, it was central to a preoccupation with the origin of the vertebrates, the group of backboned animals that includes ourselves. Although lacking a distinct head, organs of special sense or paired fins, the amphioxus has a dorsal tubular nerve cord, and the stiffening axial rod known as the notochord, that are defining features of chordates — the wider group to which vertebrates belong. For much of the twentieth century, the amphioxus was neglected as a subject of study. But with Putnam and colleagues' publication[1] on page 1064 of the draft genome sequence of *Branchiostoma floridae*, one of the 25 or so recognized species of amphioxus, this eldritch organism is set to re-enter public life.

The amphioxus was originally described by P. S. Pallas in 1774 as a kind of slug. It took almost another hundred years before Alexander Kowalevsky recognized the chordate affinities of this organism[2] as well as of tunicates (sea squirts)[3] — the other group of invertebrate chordates — and the golden age of the study of vertebrate evolution began.

In those days, the amphioxus was seen as a vertebrate writ small, bearing clues to our own lost ancestry. No issue of the *Quarterly Journal of Microscopical Science* seemed complete without a study on amphioxus anatomy or development from luminaries such as E. Ray Lankester[4], so that, by 1932, E. G. Conklin[5] felt it necessary to preface a weighty treatise on amphioxus embryology with an apology to his readers for having to wade through yet another substantial work on this creature. But the question of the origin of vertebrates fell from favour because of its abiding intractability, and because of the arrival of genetics and of model organisms such as fruitflies that are easier to study in the laboratory.

The amphioxus was never abandoned, however. In recent years the flame has been kept alive by researchers such as Nicholas and Linda Holland of the Scripps Institution of Oceanography in San Diego, as well as (the unrelated) Peter W. H. Holland at the University of Oxford and an increasing band of students and colleagues. The age of genomics has rescued the amphioxus from chthonic obscurity, as new data — now including Putnam and colleagues' paper[1] and three companion reports in *Genome Research*[6–8] — have reinvigorated the study of the origin of the vertebrates.

The genome of any species, although informative, is hardly more than a matter of record. Two genomes are more interesting, because comparisons can be made between them. But when one has three or more, one can start to frame rather precise hypotheses about the course of genomic evolution, and ask meaningful questions about the origin of morphological novelties. The 520-megabase genome of *B. floridae* would, therefore, be nothing much more than a curiosity without the comparative context offered by the increasing number of completed or draft animal genomes from humans to sea anemones, and in particular those of the tunicates *Ciona intestinalis*[9] and *Oikopleura dioica*[10]. Such studies reveal the amphioxus genome to be, in fact, of preternatural importance. Recent work[11] showing that the amphioxus is the most basal chordate, and not a close relative of vertebrates as had previously been thought, only increases its importance in our understanding of fundamental features of the chordate ancestral condition.

The draft genome underscores the basal position of the amphioxus (Fig. 2, overleaf), revealing strong patterns of conserved

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Figure 1 | The amphioxus — back in public life. This species is ***Branchiostoma lanceolatum*.**

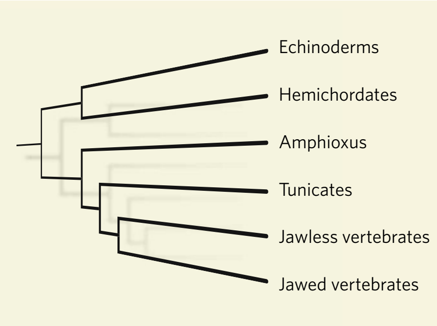

Figure 2 | Chordates and vertebrates. The chordates contain invertebrate groups (amphioxus and tunicates) and vertebrate groups (the jawless vertebrates, such as the lamprey, and the jawed vertebrates or gnathostomes). Amphioxus is the most 'basal' of chordates, a conclusion[11] confirmed by the draft genome sequence of *Branchiostoma floridae*[1]. The closest non-chordate invertebrate relatives of amphioxus are the hemichordates (acorn worms and their allies) and echinoderms (sea urchins and allies).

'synteny' with vertebrate genomes, including the human genome. This shared possession of similar blocks of genes (even though the genes within each block might have been shuffled substantially) is notable, given that the last common ancestor of the amphioxus and vertebrates lived more than 550 million years ago. More remarkable still is the presence of modest amounts of sequence homology between stretches of non-protein-coding DNA in humans and the amphioxus. This information suggests that whatever the common ancestor of all chordates looked like, its genome was similar to that of a modern amphioxus. Such findings also illustrate the degree of morphological and genomic divergence of tunicates from the chordate lineage. Although sequence homology shows tunicates to be more closely related to vertebrates than is the amphioxus[11], their unique pattern of development has been accompanied by dramatic genomic rearrangements and losses of both coding and noncoding stretches of DNA.

This extensive synteny has allowed substantive insight into a suspected episode in the early history of vertebrates when the genome underwent tetraploidization (that is, became quadrupled). Work on the amphioxus shows that this episode — or two closely linked episodes of diploidization, one following hard on the heels of the other — occurred at around the time that the lineage of jawless vertebrates, now represented by forms such as the lamprey (*Petromyzon*), emerged. The extent to which this genomic storm was manifested in the origin of morphological novelty is not known. Yet it is not unreasonable to suggest that it was connected with the origin of gnathostomes —vertebrates with jaws and paired limbs. This is a subject that is little explored as yet, but is likely to be the subject of revelations in coming years, both from genomics and from the discovery of fossil forms. ■

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SUPERCONDUCTIVITY

Prospecting for an iron age

Paul M. Grant

Different material options for high-temperature superconductivity — conduction of electricity with little or no resistance at 'practical' temperatures — have arrived. Iron compounds are the latest thing.

High-temperature superconductivity is back in the public eye, and with a bang. But as ever with this topic, we must first journey back to 1986 and 1987, and to Georg Bednorz and Alex Müller[1], and Paul Chu and his colleagues[2]. To start with, there was the headline news[1] of the onset of superconductivity in a previously unexplored class of compounds, the copper oxide perovskites, or layered cuprates, at the then record-setting temperature of 35 kelvins. Shortly afterwards[2], this transition temperature (T_c) was pushed up to 90 K — beyond the temperature of liquid nitrogen.

The initial announcement prompted practically every superconductivity centre on the planet, including my own home lab at IBM Almaden, to ransack the periodic table hoping to strike pay dirt again. So frantic became the search that Tom Lehrer's 1950s classic *The Elements* was chosen as the theme song for a 1988 BBC Horizon documentary, *Superconductor — Race for the Prize*. Special attention was paid to oxides of the first-row transition metals, running from scandium to zinc, with iron compounds among them, in the hope that a companion to copper would emerge. Alas, although the ensuing years saw the transition temperatures climb to 135 K by 1993 (165 K under pressure), that hope remained unfulfilled. The central cation remained copper, complexed in a plane of nearest-neighbour oxygen anions. And the dream of superconductivity at anything close to room temperature, around 300 K, has remained just that.

It now seems we should have looked not only at the transition-metal oxides but also at the transition-metal pnictides — compounds that contain elements from group V (now group 15) of the periodic table, such as nitrogen, phosphorus and arsenic. In mid-May of 2006, a Japanese collaboration[3] reported superconductivity with T_c ~5 K in a compound of stoichiometry originally $La(O_{1-x}F_x)FeP$, consisting of alternating layers of lanthanum-series oxyfluorides and tetrahedrally coordinated ferrous pnictide (Fig. 1). By January 2008 the same group[4] had lifted T_c to 26 K on substituting arsenic for phosphorus, and in April that was raised[5] to 43 K, albeit under an applied pressure of 4 gigapascals. In the meantime, the appearance of papers on the preprint server arXiv posted by a collaboration in China sparked rumours of a T_c of 54 K in $Sm(O_{1-x}F_x)FeAs$. Late last month, that group published a paper[6] describing a T_c of 53.5 K in a pnictide with gadolinium in the lanthanum position.

The increase of T_c in the ferrous pnictides from 2006 and its acceleration since January 2008 is reminiscent of the 'hockey stick' graph seen two decades earlier for increasing T_c in the layered cuprates. Over the past four months, the pnictides have spawned unprecedented numbers of submissions to the condensed-matter part of the arXiv site, sometimes three a day. Most of these contributions are theoretical in nature (theory being a much safer pursuit than experiment, at least physically, especially when a synthesis involving arsenic compounds is concerned), bringing to mind a comment by the late Pierre de Gennes. At a conference that followed the discovery of high T_c, de Gennes admitted that all theoreticians have a "clothes closet" of favourite "models, or suits ... used, unused and over-under-sized", and that when some new superconductor is found they will pull one out, try it on, and "see if it fits".

Where do we go from here? Well, to start with we can see several striking similarities between the ferrous pnictides and the layered copper oxide perovskites. First, both are layered systems. Second, the Ln–O–F layers provide 'charge reservoirs' for doping; they also sterically reduce the overall symmetry with respect to the intervening ferrous pnictide transport planes, quite possibly driving 'Jahn–Teller-like' phonon-driven instabilities. Third, both systems are, to varying degrees, spin-correlated,