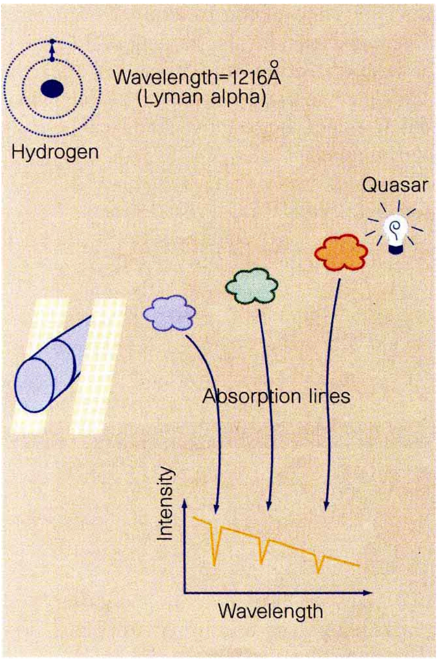

Figure 2 **Clouds of gas between us and a distant quasar all absorb light at the same (Lyman-alpha) wavelength in their own rest-frame, but because they have different redshifts, many separate absorption lines are seen — the Lyman forest.**

diverse structure of the Lyman forest, using the popular cold-dark-matter model of galaxy formation. This work has led to a blurring of the distinction between the forest clouds and the intergalactic medium: in the cold-dark-matter model, the hard work of forming structure in the Universe is done by the dark matter, which carries essentially all of the mass, and the normal baryonic component is merely 'along for the ride', slowly collecting in the potential wells created by the gravitational collapse of the dark matter. In this picture, there are no well-defined forest 'clouds' as such, but rather a single, continuous medium filling the volume of intergalactic space, yet showing large, but smooth, variations in density and velocity along any given line of sight (Fig. 1). The seemingly continuous nature of the He^+ absorption seen in the new spectrum of Q0302–003 is consistent with this.

The ionization levels inferred from the Q0302–003 spectrum are also consistent with the notion that most normal matter at high redshift hides in the ionized component of the Lyman forest. Recent measurements of the deuterium content of the Lyman-forest clouds[9,10], applied to theories of nucleosynthesis in the Big Bang, constrain the baryonic content of the Universe to no more than a few per cent of the critical density (required for a just-closed Universe) — an amount that can readily be found in the helium data.

We can hope to see further improvements in the detection of intergalactic He^+ absorption in the coming years, once STIS — the advanced ultraviolet spectrograph that was successfully substituted for the Goddard Spectrograph during the recent Hubble Telescope servicing mission — comes on line. □

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Avian origins

A new missing link

Lawrence M. Witmer

Among evolutionary debates, perhaps only the origin of humans has attracted as much attention as avian origins. Less than two years after Darwin's *Origin of Species* hit the shelves, a spectacular 'missing link' between birds and reptiles was unearthed in Germany: the famous 'feathered reptile' *Archaeopteryx lithographica*, which immediately became central not only to the debate on the evolution of birds, but to the debate on evolution itself. Now, on page 390 of this issue, Novas and Puerta[1] announce the discovery of a new intermediate form, which may help to fill in the details of the functional transition between reptiles and birds.

Since the 1860s, scientists have debated which of the various reptilian groups is genealogically the closest to *Archaeopteryx*. Most of the main groups of archosaurs have been linked with birds at one time or another but, for the past 20 years[2], there has been a broad consensus (although not without dissent[3]) that birds are related to a group of small, bipedal, carnivorous dinosaurs known as theropods. Among theropods, dromaeosaurid coelurosaurs such as *Deinonychus* and *Velociraptor* are usually regarded as the closest relatives of *Archaeopteryx* and other birds[4,5]. But a troubling (if narrowed) morphological gap has remained, impeding attempts to tease apart the details of the functional transition.

Novas and Puerta[1] now describe a non-avian theropod dinosaur which they call *Unenlagia comahuensis*, from the early Late Cretaceous (90 million years ago) in Patagonia, Argentina. *Unenlagia* slots in cladistically between dromaeosaurids and *Archaeopteryx*. It was a relatively small theropod, perhaps only two-thirds the size of *Deinonychus*, and, typical of these small, fragile theropod skeletons, *Unenlagia* is known from only a handful of bones. Nevertheless, Novas and Puerta have selected an apt name in that *Unenlagia* means 'half bird', and it indeed combines an almost even mixture of primitive coelurosaurian and derived avian characters. For example, the *Unenlagia* ischium (Fig. 1) has the typical triangular obturator process that is found in most advanced coelurosaurs, as well as a process that is found only in *Archaeopteryx* and other

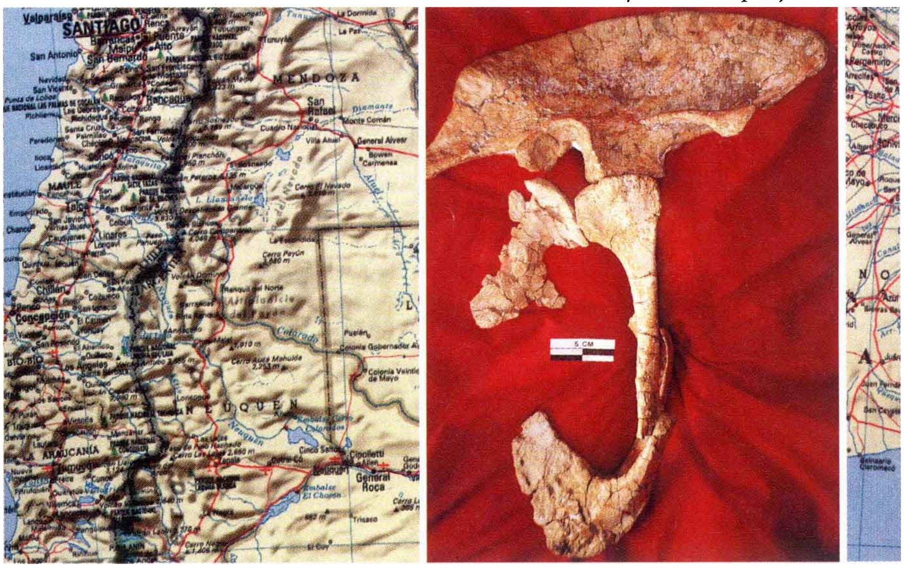

Figure 1 **Novas and Puerta[1] have used a small number of bones to build up a picture of a new intermediate form (*Unenlagia comahuensis*) between reptiles and birds. The bones were found in the Patagonian badlands (Neuquén Province), and the *Unenlagia* pelvis is shown. The pelvis has features that are found both in birds and in most advanced coelurosaurs. (Photo courtesy of F. E. Novas.)**

birds. The ilium has the usual excavation for a certain muscle found in coelurosaurs, yet it also has an extensive inner wall to the hip socket, much as in *Archaeopteryx* and other basal birds. This was unexpected because non-avian dinosaurs almost always have a fully open socket. The pubis is at a dromaeosaurid grade of retroversion, meaning that it is directed more towards the rear than in more primitive coelurosaurs, but not as far as in *Archaeopteryx* and other birds. Moreover, the pubis has a large coelurosaur-like distal expansion, or 'boot', yet, as in all birds, *Unenlagia* has totally lost the primitive forward 'toe' of the boot. So *Unenlagia* is a true mosaic, begging the question of where to draw the line between what is, or is not, a 'bird'.

The one feature that will raise the most controversy is the orientation of the shoulder joint in *Unenlagia*. Novas and Puerta believe that the joint surface faces laterally, as in *Archaeopteryx* and other birds. But this would be totally unlike non-avian dinosaurs, in which the shoulder socket faces more down and back. With a laterally facing joint surface, *Unenlagia* could raise its forelimb extensively, producing a full upstroke in preparation for a long, down-and-forward 'flight stroke'. Furthermore, the orientation is another step towards the wing-folding mechanism which, in birds, allows the long flight feathers to be safely tucked away. So according to Novas and Puerta, *Unenlagia* shows that many of the features that we associate with avian flight evolved in a terrestrial context — and perhaps flight evolved 'from the ground up', without an intervening arboreal, gliding phase.

This interpretation will be controversial because the orientation of the shoulder socket is dependent on the orientation of the scapula, which is not fixed to the rib cage, but rather 'floats' in muscle. If the scapula is placed in an avian position, the socket faces laterally, whereas in a more dromaeosaurid-like position, the orientation of the socket is less avian. But some features of the scapula of *Unenlagia* support an avian orientation. For example, the shaft of the scapula is twisted to lie on the back, as in most birds. Perhaps more importantly, there is a prominent, projecting acromion process that is very similar to that found in *Archaeopteryx* and other birds, but which is not found in non-avian theropods. These features may signal the restructuring of the shoulder girdle along avian lines.

Might we then suppose that *Unenlagia* had feathers? Certainly no feathers were preserved, but given the nature of the rocks in which *Unenlagia* was found, this is not surprising. Although it is tempting to speculate that feathers, and perhaps even incipient flight, honed these bird-like attributes of *Unenlagia*, there is as yet no evidence for this. Novas and Puerta[1] are appropriately cautious, regarding *Unenlagia* as a relic descendant of a lineage that diverged just before the fully feathered and flying line that leads to *Archaeopteryx* and true birds. In fact, some of the common features may ultimately have been co-opted for flight, but they could have originated in a completely different functional context. What could this context have been? Unfortunately, forelimb function in advanced coelurosaurs is poorly understood, particularly with regard to joint mobility and excursion. Until such biomechanical questions are resolved, an arboreal climbing model may be as valid as a terrestrial predation model in explaining the transition to birds. But regardless of the final interpretation of the functional transition, *Unenlagia* is a critical testament of the phylogenetic transition, and it is only after the phylogenetic players are better known that the drama of the adaptive story will be truly comprehensible. □

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Host–guest chemistry

Crowns get organized

Thomas E. Mallouk

By combining organic and inorganic building blocks, composite materials can be created that embody the most useful features of both. In a recent article[1], Baolong Zhang and Abraham Clearfield describe a lamellar solid made of zirconium phosphonate sheets, which are held apart by crown ether molecules. The crystalline inorganic framework controls the juxtaposition of these organic hosts, and the access of other molecules and ions, making the whole a promising structure for designed sensors, separations media and catalysts.

Small guest molecules bind to macromolecular hosts in many important chemical processes. This binding is a prerequisite for the function of enzyme active sites, chromatographic media and many heterogeneous catalysts. As with Cinderella's glass slipper, a good fit is needed for the guest to bind tightly to the host: oversized guests do not fit, and small ones come loose on the palace steps. Some inorganic solids, such as zeolites and clays, contain cavities that are just right, and these materials also tend to be stable in chemically aggressive environments. They are of great interest in separations technologies, for example[2,3] in the extraction of radioactive Cs^+ and Sr^{2+} from liquid wastes containing a vast excess of Na^+. Unfortunately, crystalline solids are not always amenable to design — the strong chemical bonds that hold together inorganic materials are also structure-directing, and make dense structures much more common than open ones.

In contrast, organic hosts (like slippers) can be made in many sizes, and their names (crowns, cavitands, cryptands, torands, cyclams, and so on) describe a rich variety of shapes. So one can usually be chosen or designed to select the appropriate guest from a mixture. Crown ethers are so called because they resemble a crown, the points being oxygen atoms that attach themselves to metal ions and neutral solutes. They have been widely used in chemical analysis[4] and separations[5], and their high affinity for cations has more recently stimulated applications in phase-transfer catalysis. Although cation-selective hosts are most common, molecules that bind anions have also been developed[6,7].

But the common problem with organic hosts is that, to be recovered easily after a separation or catalysis, they must be anchored to insoluble supports such as polymers[8,9] or silica[10]. Attached randomly to the surface of these materials, the host molecules experience a range of microenvironments, and there is no control over their juxtaposition, which might otherwise be used to advantage in applications that require cooperative binding. Such materials are also difficult to characterize precisely, because of their heterogeneity and amor-

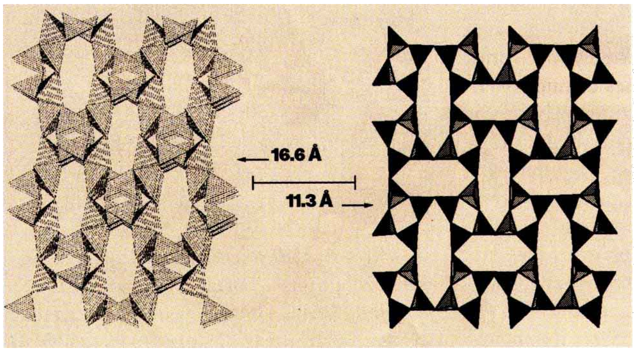

Figure 1 **Molecular minerals. Like oxygen, the pyrimidine ligand makes two angled bonds, so the copper–pyrimidine network (left) resembles that of a feldspar, $MAlSi_3O_8$ (right). By mimicking minerals, active organic molecules can be assembled into stable, predictable structures.**