The ‘wishbone’ of birds comprises two clavicles fused into a structure known as a furcula. In an influential 1926 book on bird origins by Heilmann3, the furcula’s supposed absence in dinosaurs was considered powerful evidence barring them from bird ancestry. A furcula has now been found in several theropod dinosaurs4,5, but its absence in other theropods, and the uncertainty of whether this absence is real or an artefact of preservation, obscures the evolutionary history of this structure6. Here we report the discovery of a furcula in Dromaeosauridae, a group posited to be the closest relative of birds6,7.

Among close bird relatives (non-avian Maniraptora), a furcula is known only in Oviraptoridae6. Although a furcula was tentatively reported to be present in an articulated skeleton of Velociraptor mongoliensis preserved embracing a close relative of birds6,7, the only firsthand description of this specimen maintained that it is not present8, and our observations of that specimen confirm this. A furcula has not been identified in any of the other five described species of Dromaeosauridae. Other taxa either lack any evidence of clavicles or, in one troodontid specimen9, clavicles are present but not fused. But the rarity of articulated specimens, the similarity of the furcula to ribs and gastralia, and incomplete preservation, conspire to obscure whether this absence is real.

A partial skeleton of Velociraptor mongoliensis (specimen IGM 100/976) was discovered at Tugrugyn Shireh, Mongolia, during the 1991 expedition of the Mongolian Academy of Sciences–American Museum of Natural History Expedition. The specimen consists of a nearly complete skull and anterior part of the skeleton, prelude to obscuring whether this absence is real or an artefact of preservation or ontogenetic sampling8.

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The bones are heavily bioturbated, and many elements are punctured by borings similar to those often present in Djadokhta Formation sediments11, but the specimen is otherwise very well preserved and articulated. The block that holds the furcula also preserves a pair of sternal plates, posterior cervical vertebrae, the proximal ends of both ribs, the gastralia, and incomplete preservation confuses. But the rarity of articulated specimens underscores the difficulty of assessing whether the apparent absence of this feature is real or an artefact of preservation or ontogenetic sampling.

The discovery of a furcula in a taxon previously known from an articulated specimen underscores the difficulty of assessing whether the apparent absence of this feature is real or an artefact of preservation or ontogenetic sampling.

The furcula is in articulation between the scapulocoracoid anterior to the sternal plates (Fig. 1), in the same position as in oviraptors and birds. The bone is ‘V’-shaped and very slender, much thinner than in oviraptors and Archaeopteryx. In cross-section it is nearly circular. A short midline process, the hypocleidium, extends posteriorly. The proximal, or epicleidial, process sweeps posterodorsally to articulate with the acromion of the scapulocoracoid. The proximal process of the furcula tapers to a point where it contacts the scapulocoracoid, and the posterior articulating surface contacting the acromion is smooth.

The broad distribution of a furcula among the non-flying relatives of birds4,5,9,12 indicates that its origin is not tied to the origin of flight. The furcula’s use in powered avian flight is therefore a co-option of a structure already present before flight evolved in the lineage leading to modern birds1. The discovery of a furcula in a taxon previously known from an articulated specimen underscores the difficulty of assessing whether the apparent absence of this feature is real or an artefact of preservation or ontogenetic sampling.

Figure 1 V. mongoliensis specimen IGM 100/976 with ‘V-shaped furcula. a, Ventral view of anterior trunk region: c, posterior cervical vertebrae; f, furcula; lc, left coracoid; r, right ribs; lst, left sternal plate; rst, right sternal plate; rh, right humerus; rs, right scapula; rr, right coracoid. b, Detail of same region.
media. The latex particles accumulated slowly on the membrane surface, building up closely packed, ordered layers roughly 10 μm thick. The deposited crystalline layer could be broken and detached from the membrane surface for analysis by light and scanning electron microscopy (Fig. 1).

To induce silica polymerization the microsphere surfaces had to be functionalized in situ by adsorption of the surfactant hexadecyltrimethyl ammonium bromide (HTAB). We soaked the crystalline latex layers with 0.02 M HTAB solution for 20 min, then removed the excess unadsorbed surfactant by washing briefly with deionized water. We mineralized the cavities in the arrays by passing 0.5 M silica solution through the latex-covered filter. The permeability of the layers decreased as the polymerization process continued, so that flow through the filter stopped in less than one minute. When the silica solution had gelled inside the colloidal crystal layer, we removed the excess solution and dried the latex/silica composite under vacuum. The latex templates inside the polymerized silica were used as templates. Large ordered arrays of spherical cavities, representing a negative replica of the original colloidal crystal embedded in the silica, are seen. The silica flakes appear to be built up of many similar domains with different crystal orientations. Details of materials and methods are available on request from the authors. Scale bars, 1 μm.

1 μm. A comparison between the repeat units of the silica replicas and the original latex crystals showed that the baked materials had shrunk by 20–35%, a value that is higher than, but comparable to, that in the M41S mesoporous silica.

Our results show that it is possible to obtain highly structured silica materials in which the pore size, shape and ordering can be precisely controlled within a wide range that has previously been unattainable. The method is powerful and controllable, and could be adapted for large-scale production.

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We studied transgenic mice expressing human PrP (HuPrP105 Prn-p105), which have been shown to lack a species barrier to human prions from one iatrogenic CJD case3, comparing them with non-transgenic (FVB) mice. All of 16 further CJD cases, encompassing a wide range of clinicopathological phenotypes, all three PrP types reported in sporadic and acquired prion diseases4 and all PrNP genotypes at polymorphic codon 129, a key determinant of genetic susceptibility to human prion diseases5–6, were transmitted to these transgenic mice.

Almost all inoculated transgenic mice contracted disease with similar short incubation periods, consistent with a lack of species barrier to these isolates (Table 1). These transgenic mice express human PrP homozygous for valine at codon 129. However, there was no significant difference in mean incubation periods between inoculation of the different codon 129 genotypes. PrP+ typing of these transmissions showed that the same prion types seen in sporadic and iatrogenic CJD (types 1–3) are produced, distinct from that seen in vCJD (type 4). Only occasional transmissions, at longer and variable incubation periods, were seen in FVB mice.

In contrast, efficient transmission of vCJD to FVB mice was observed (Table 1) although incubation periods were prolonged. Conversely, the attack rate of vCJD in the transgenic mice was reduced in comparison to typical CJD, and incubation periods were generally more variable and prolonged. Mean incubation periods to these six vCJD cases were similar in both types of mice. The clinical course in vCJD-inoculated transgenic mice was much longer than in transmissions of typical CJD. vCJD in humans is also associated with a long clinical duration7. Some mice, as well as showing typical neurological features, persistently walked backwards. This unusual clinical sign was not seen in transmissions of typical CJD, fatal familial insomnia or other