Bird evolution

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Archaeopteryx at Paläontologisches Museum München

The **evolution of birds** is thought to have begun in the Jurassic Period, with the earliest birds derived from theropod dinosaurs. Birds are categorized as a biological class, **Aves**. The earliest known species of class Aves is *Archaeopteryx lithographica*, from the Late Jurassic period, though Archaepteryx is not commonly considered to have been a true bird. Modern phylogenies place birds in the dinosaur clade Theropoda. According to the current consensus, Aves and a sister group, the order Crocodilia, together are the sole living members of an unranked "reptile" clade, the Archosauria.

Phylogenetically, Aves is usually defined as all descendants of the most recent common ancestor of a specific modern bird species (such as the *Passer domesticus*), and either *Archaeopteryx*,[1] or some prehistoric species closer to Neornithes (to avoid the problems caused by the unclear relationships of *Archaeopteryx* to other theropods).[2] If the latter classification is used then the larger group is termed Avialae.

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There is significant evidence that birds evolved from theropod dinosaurs, specifically, that birds are members of Maniraptora, a group of theropods which includes dromaeosaurs and oviraptorids, among others.[3] As more non-avian theropods that are closely related to birds are discovered, the formerly clear distinction between non-birds and birds becomes less so. Recent discoveries in northeast China (Liaoning Province), demonstrating that many small theropod dinosaurs had feathers, contribute to this ambiguity.[4]

The basal bird *Archaeopteryx*, from the Jurassic, is well-known as one of the first "missing links" to be found in support of evolution in the late 19th century, though it is not considered a direct ancestor of modern birds. *Confuciusornis* is another early bird; it lived in the Early Cretaceous. Both may be predated by *Protoavis texensis*, though the fragmentary nature of this fossil leaves it open to considerable doubt if this was a bird ancestor. Other Mesozoic birds include the *Confuciusornis*, the Enantiornithes, *Yanornis*, *Ichthyornis*, *Gansus*, and the Hesperornithiformes - a group of flightless divers resembling grebes and loons.

The recently (2002) discovered dromaeosaur *Cryptovolans* (which may be a *Microraptor*) was capable of powered flight, possessed a sternal keel and had ribs with uncinate processes. In fact, *Cryptovolans* makes a better "bird" than *Archaeopteryx* which is missing some of these modern bird features. Because of this, some paleontologists have suggested that dromaeosaurs are actually basal birds whose larger members are secondarily flightless, i.e. that dromaeosaurs evolved from birds and not the other way around. Evidence for this theory is currently inconclusive, but digs continue to unearth fossils (especially in China) of the strange feathered dromaeosaurs. At any rate, it is fairly certain that flight utilizing feathered wings existed in the mid-Jurassic theropods and was "tried out" in several lineages and variants by the mid-Cretaceous, such as in *Confuciusornis* which had some peculiar features. For example, its vestigial tail was unfit for steering, and its wing shape seems rather specialized although the arm skeleton was still quite "dinosaurian").

Confuciusornis, a Cretaceous bird from China. Note wing claws and lack of tail.

Although ornithischian (bird-hipped) dinosaurs share the same hip structure as birds, birds actually originated from the saurischian (lizard-hipped) dinosaurs if the dinosaurian origin theory is correct. They thus arrived at their hip structure condition independently. In fact, the bird-like hip structure also developed a third time among a peculiar group of theropods, the Therizinosauridae.

An alternate theory to the dinosaurian origin of birds, espoused by a few scientists (notably Larry Martin and Alan Feduccia), states that birds (including maniraptoran "dinosaurs") evolved from early archosaurs like *Longisquama*,[5] a theory which is contested by most other paleontologists, and by experts in feather development and evolution[6].

Adaptive radiation of birds

Modern birds are classified in Neornithes, which are now known to have evolved into some basic lineages by the end of the Cretaceous (see *Vegavis*). The Neornithes are split into the paleognaths and neognaths.

Paleognathae
The paleognaths include the tinamous (found only in Central and South America) and the ratites which nowadays are found almost exclusively on the Southern Hemisphere. The ratites are large flightless birds, and include ostriches, cassowaries, kiwis and emus. A few scientists propose that the ratites represent an artificial grouping of birds which have independently lost the ability to fly in a number of unrelated lineages[*citation needed*]; in any case, the available data regarding their evolution is still very confusing.

Neognathae
The basal divergence from the remaining Neognathes was that of the Galloanserae, the superorder containing the Anseriformes (ducks, geese and swans), and the Galliformes (the pheasants, grouse, and their allies).

The dates for the splits are a matter of considerable debate amongst scientists. It is agreed that the Neornithes evolved in the Cretaceous and that the split between the Galloanserae and the other neognaths - the Neoaves - occurred before the K-T extinction event, but there are different opinions about whether the radiation of the remaining neognaths occurred before of after the extinction of the other dinosaurs.[7] This disagreement is in part caused by a divergence in the evidence, with molecular dating suggesting a Cretaceous radiation, a small and equivocal neoavian fossil record from Cretaceous, and most living families turning up during the Paleogene. Attempts made to reconcile the molecular and fossil evidence have proved controversial.[7][8]

On the other hand, two factors must be considered: First, molecular clocks cannot be considered reliable in the absence of robust fossil calibration, whereas the fossil record is naturally incomplete. Second, in reconstructed phylogenetic trees, the time and pattern of lineage separation corresponds to the evolution of the *characters* (such as DNA sequences, morphological traits etc) studied, *not* to the actual evolutionary pattern of the lineages; these ideally should not differ by much, but may well do so in practice.

Considering this, it is easy to see that fossil data, compared to molecular data, tends to be more accurate in general, but also to underestimate divergence times: morphological traits, being the product of entire developmental genetics networks, usually only start to diverge some time *after* a lineage split would become apparent in DNA sequence comparison - especially if the sequences used contain many silent mutations.

Classification of modern species

see also: Sibley-Ahlquist taxonomy and dinosaur classification

The phylogenetic classification of birds is a contentious issue. Sibley & Ahlquist's *Phylogeny and Classification of Birds* (1990) is a landmark work on the classification of birds (although frequently debated and constantly revised). A preponderance of evidence suggests that most modern bird orders constitute good clades. However, scientists are not in agreement as to the precise relationships between the orders; evidence from modern bird anatomy, fossils and DNA have all been brought to bear on the problem but no strong consensus has emerged. As of the mid-2000s, new fossil and molecular data provide an increasingly clear picture of the evolution of modern bird orders, and their relationships. For example, the Charadriiformes seem to consititute an ancient and distinct lineage. Our understanding of the interrelationships of lower level taxa also continue to increase, particularly in the massively diverse perching bird order Passeriformes.

Current evolutionary trends in birds

See also: Bird conservation

Evolution generally occurs at a scale far too slow to be witnessed by humans. However, bird species are currently going extinct at a far greater rate than any possible speciation or other generation of new species. The disappearance of a population, subspecies, or species represents the permanent loss of a range of genes.

Another concern with evolutionary implications is a suspected increase in hybridization. This may arise from human alteration of habitats enabling related allopatric species to overlap. Forest fragmentation can create extensive open areas, connecting previously isolated patches of open habitat. Populations that were isolated for sufficient time to diverge significantly, but not sufficient to be incapable of producing fertile offspring may now be interbreeding so broadly that the integrity of the original species may be compromised. For example, the many hybrid hummingbirds found in northwest South America may represent a threat to the conservation of the distinct species involved[9].

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