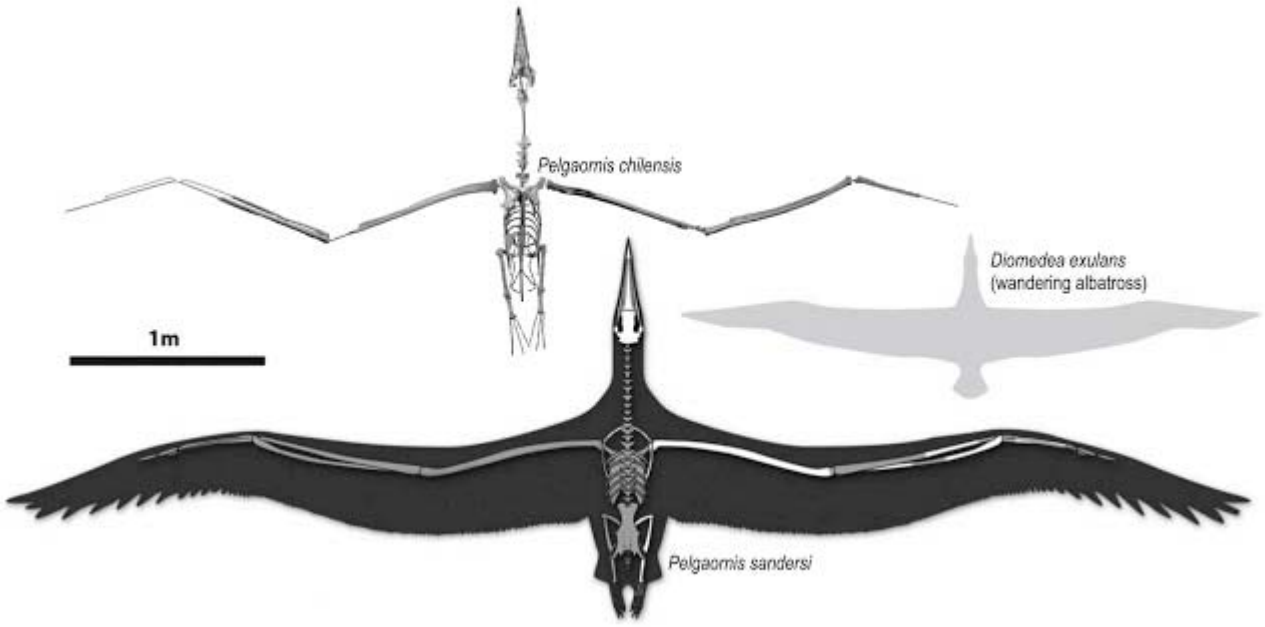
The Origin of Modern Birds

This talk was given at the Denver Museum of Natural History by Dr. Daniel J. Field, a lecturer at the Department of Earth Sciences at Cambridge University. Dr. Field is a Research Associate at the Denver Museum of Natural Science and a Fellow in Natural Sciences at Christ's College, Cambridge. He discussed how the K-T Mass Extinction affected the evolution on modern birds.

Birds are the most ubiquitous and widespread vertebrate animals with nearly 11,000 species of different shapes, colors and sizes. Can the diversity be explained by extensively examining the fossil record? The last 10 years have been an exciting time to examine the origin of birds due to advances in genome sequencing, and in computing power to analyze vast datasets.

The only direct method of determining bird evolution is the fossil record. For example, the pseudo-toothed birds, or pelagornis, can be traced to modern-day ducks and chickens. The name derives from the boney projections on the sides of their bills which are a re-invention of teeth. They are the largest flying birds to have ever lived, from the Paleocene to the Pleistocene, and the only way we know of their existence is through the fossil record. You can see representative size in the illustration comparing *Pelagornis* to the modern-day albatross. It is reconstructed in the Bird Hall of the Denver Museum.



The closest relatives of birds are crocodilians which are in a group called the archosaurs, whose most recent common ancestor lived over 200 million years ago. To determine how feathers and the toothless beak arose it is necessary to

study the record of dinosaurs in the Mesozoic Period in the Avian Stem Group. Colleagues of Dr. Field were fortunate enough to be able to examine a recently discovered relatively intact member of this group called icthyornis, (meaning "fish bird", after its fish-like vertebrae), which is the genus of toothed seabird-like ornithuran. From these remains they were able to reconstruct a 3-D model of this predecessor of modern birds showing the earliest manifestation of a toothless avian beak.

A technique called clumped isotope paleo-thermometry used on fossil dinosaur eggshells shows that Mesozoic dinosaurs all exhibit body temperatures that were within the range of variation of modern birds, indicating that avian warm bloodedness is an ancient feature. Recent discoveries in China have revealed that the evolution of feathers and controlled flight occurred much later in avian evolutionary history than was previously thought.

The Avian Crown Group includes the most recent common ancestors of all modern living birds and their living descendants. Fossils from this group can shed light on when divergences in bird evolution took place. Dr. Field has been focusing on a group of birds called the passerines, or perching birds, which is the most common bird type with over 6,000 species. Dr. Field and colleagues sequenced the genomes of various passerines to determine their evolutionary history and found that periods of geologic change in the Cenozoic had little effect on passerine diversification. This suggests that more complex factors had driven diversification. For example, hummingbirds and swifts are related. Early hummingbirds were already adapted for hovering flight, but had large skulls and short beaks like swifts, signifying that that they were aerial insectivores like swifts.

The fossil record can tell where on the earth's surface modern birds originated. A fossil bird (foro panarium) found in the Green River Formation of Wyoming is closely related to modern turacos. Today, Wyoming is much too cold for turacos for most of the year, but during the early Palaeogene period, which began with the extinction of non-avian dinosaurs 66 million years ago, the Earth was much warmer. Over time, global climates have cooled considerably, and the ancestors of modern turacos gradually shifted their range to more suitable areas. They are currently found in sub Saharan Africa. Hummingbirds and rollers also show this geographical shift. Hummingbirds originated in Europe. The geographical distribution of modern birds has fluctuated with climate enormously over their history. Dr. Field and his associate Dr. Erin Saupe, another North American currently at the University of Oxford, have recently published results of their studies on this subject in the *Proceedings of the National Academy of Sciences*.

Great Blue Turaco (Corythaeola cristata), Entebbe Botanical Gardens, Uganda.

Dr. Field regards the Cretaceous Mass Extinction as the most pivotal event in bird's evolutionary history. The fossil record shows that the Avian Stem Group is confined to the Mesozoic while the Avian Crown Group is entirely confined to the Cenozoic. The oldest fossil for the Crown Group is 67 million years old. As the Cretaceous Mass Extinction occurred 66 million years ago, it is probable that this event ultimately gave rise to modern birds. Calibrating the rate of genetic change with the fossil record provides a time scale for bird evolution. This time scale shows that most divergence in bird's evolutionary history began 66 million years ago at the time of Cretaceous Mass Extinction.

What happened to the early relatives of modern birds that survived the mass extinction and what explains the differential survival of these early Crown Group Birds compared to other lineages of bird-like creatures that disappeared? Dr. Field and his colleagues suggest there is evidence that reduced body size influenced which bird groups survived the extinction. This is consistent with the "Lilliput Effect", where smaller animals survive certain catastrophic events due to their lower metabolic requirements. The rate of genome substitution is up to 20 times higher in smaller than larger birds, which may have led to a pulse of genetic evolution after the mass extinction. Geophysical models indicate that immediately after the meteor impact, large swathes of the earth's surface were at a higher temperature than required for the spontaneous combustion of wood. Researchers have found an absence of tree pollen immediately after the mass extinction and an increase in fern pollen. Dr. Field hypothesizes that this deforestation would have concomitantly diminished the survival of tree dwelling species, such as the most common bird-like dinosaurs, the Enantiornithes, which had a claw adaptation developed for tree life. DNA analysis indicates that the earliest ancestors of modern birds after the mass extinction were non-arboreal.

Dr. Field mentioned that Colorado was probably one of the best places to look for the fossils of these early ancestors of modern birds. In response to an

audience question of where the best places to investigate, he replied that where there were rocks that represented the early stages of the Cenozoic, although fossils of these presumably small birds would be rare and difficult to find. He has searched the Grand Junction area without success. Another person asked if there was any direct fossil evidence of forest fires and he answered that people were researching this topic.