DO DINOSAURS STILL WALK THE EARTH?

SHREYA GHOSH

While most branches of the dinosaur family tree were wiped out during a mass-extinction event 65.5 million years ago, some of their direct descendants still live on. What do we know about these creatures, their mysterious survival, and their relationship to the dinosaurs of yore?

The tiny town of Chicxulub Puerto in south-eastern Mexico houses only a few thousand residents. A casual glance at the sleepy settlement suggests a peaceful community, one amongst many dotting the vast Yucatan peninsula. Yet, buried just about a kilometre beneath Chicxulub's surface and written in lines of quartz and melted rock lies the evidence of its uniquely violent history. The ground where Chicxulub Puerto stands today was once ground zero for one of the most catastrophic events in the history of life on earth.

On a day 65.5 million years ago, a piece of extra-terrestrial rock as big as a mountain crashed into earth with the explosive power of over a hundred trillion tons of TNT (see **Fig. 1**). Releasing more than a billion times the energy of the atomic bomb dropped on Hiroshima, the rock's impact created an almost perfectly circular crater, nearly 180 km in diameter, right atop the centre of which Chicxulub stands today (see **Fig. 2**). It resulted in a massive heat pulse, vaporizing all living forms for miles around, followed by earthquakes and massive tsunamis that radiated out in all directions. The debris and dust thrown out into the atmosphere blocked out sunlight for over a year, resulting in a nuclear winter where plants failed to grow, and predator and prey alike starved to death (see **Box 1**).

Fig. 1. Artist's rendering of an asteroid slamming into the tropical, shallow seas of the sulfur-rich Yucatan Peninsula in, what is today, southeast Mexico.

Credits: Donald E. Davis, NASA/JPL-Caltech, Wikimedia Commons. URL: https://commons.wikimedia.org/wiki/File:Chicxulub_impact_-_artist_impression.jpg. License: Public Domain.

All of this occurred in the background of an earth that was already ravaged by severe volcanism and global climate change. The **Cretaceous-Tertiary (K-T) mass extinction event**, as it is called today, ended up wiping out nearly two-thirds of all the species inhabiting the planet at the time (some estimates go as high as 80% of all life on earth).

Amongst these was a massively successful group of reptiles, of which more than a thousand species of every size had once roamed the jungles. The age of the dinosaurs had come to an end (see **Box 2**).

However, not every dinosaur perished in the K-T extinction. One unlikely group survived, and they persist to this date, nesting on our windowsills, stealing bits of food from roadside stalls, and waking us up in the morning with their cacophonous warbles.

Birds are the last living dinosaurs on our planet, and this is their story.

Box 1. The biggest asteroid collisions in earth's history:

The Chicxulub asteroid collision is rather well known because of its relative recentness and the mass extinction that followed. But it is nowhere near unique in earth's tumultuous history, and is only the third-biggest asteroid impact on earth known to humankind. Here are a couple of other big 'impacts' that have changed the face of the earth in the past:

(a) The Vrederford Crater, located in South Africa, is believed to be the second oldest and the largest known impact crater on earth. A roughly 10 km wide asteroid struck earth about 2 billion years ago, creating a crater that is more than 300 km across. Life on earth at the time consisted of single-celled organisms. We know little about the consequences of this massive event on them.

(b) The Sudbury Crater in Ontario, Canada, that is around the same size as Chixculub, was formed by an asteroid impact about 1.8 billion years ago. This impact crater later filled up with molten rock rich in minerals like nickel, copper, platinum, and gold, making this area extremely lucrative for both mining and agriculture.

Fig. 2. This shaded relief image of Mexico's Yucatán Peninsula shows a subtle, but unmistakable, indication of the Chicxulub impact crater.

Credits: NASA/JPL-Caltech, modified by David Fuchs, Wikimedia Commons. URL: https://commons.wikimedia.org/wiki/File:Yucatan_chix_crater.jpg. License: Public Domain.

Box 2. How did the Cretaceous-Tertiary (K-T) mass extinction event impact human evolution?

The aftermath of the Chicxulub impact is often known as the Cretaceous-Tertiary mass extinction event because it marks the dividing boundary between the Cretaceous and Tertiary geological eras in earth's history. Almost three-quarters of all life on earth (including plants, animals, and micro-organisms) is believed to have perished as a result of the global environmental changes that resulted from the impact.

Interestingly, a few groups of animals, including mammals, that were overshadowed by the majestic dinosaurs in the previous era, underwent massive diversification and population growth following their extinction. Perhaps, at some level, we humans owe our existence to the Chicxulub asteroid impact!

Fig. 3. The 'Berlin specimen' of *Archaeopteryx*.

Credits: Emily Willoughby, Wikimedia Commons. URL: https://commons.wikimedia.org/wiki/File:Berlin_Archaeopteryx.jpg. License: CC-BY-SA.

The ancient wings of Archaeopteryx

It was not always known that birds were related to dinosaurs. Sometime in the mid-1870s a German farmer named Jakob Niemeyer discovered a strange fossil in the Blumenberg quarry near the town of Eichstätt in Germany. In need of money to buy a cow, Niemeyer decided to sell the fossil to a local innkeeper. After changing hands a few more times, the fossil was finally bought by the Natural History Museum of Berlin in 1881, for the princely sum of 20,000 gold marks. This 'Berlin specimen', as it came to be called, contains an excellently preserved skeleton and skull of a creature with spread wings, a bony tail, and three claws at the end of each 'hand' (see **Fig. 3**). What Niemeyer had discovered, and sold for want of a cow, remains one of the most perfect and complete specimens of *Archaeopteryx* till date. With a name derived from Greek 'archaīos' meaning ancient, and 'ptéryx' meaning wing, it was our first clue to the mysterious origins of modern birds.

Archaeopteryx was first described in 1861, by the German palaeontologist Christian Erick Hermann von Meyer, using a single fossilized feather. The first skeleton was unearthed in the same year from a quarry near Langenaltheim in Germany. In an uncanny parallel with Niemeyer, the unknown discoverer of this specimen gave the fossil as payment to a local doctor, who sold it to the Natural History Museum in London. So, what makes this prehistoric bird, that lived almost 160 million years ago, unique?

Archaeopteryx had a near-perfect mix of reptile-like and bird-like features. About the size of a big crow, it had a long tail and jaws with sharp teeth like a reptile, but also sported two large feather-covered wings and three-fingered hands like modern birds (see **Fig. 4**). *"Hardly any recent discovery shows more forcibly than this how little we as yet know of the former inhabitants of the world,"* wrote Charles Darwin, the father of evolutionary biology, in the 4th edition of *On the Origin of Species* (1866).

Fig. 4. Illustration of *Archaeopteryx lithographica* chasing a juvenile compsognathid *(Compsognathus longipes)* through Late Jurassic Germany at night.

New theories and old theories

Thomas Huxley, an English biologist and a great proponent of Darwin's theory (to the extent that many people called him 'Darwin's bulldog'), was the first to note the similarities between the skeletons of birds and theropods. Theropods are a class of dinosaurs characterized by hollow bones, and three toes on each arm and leg (see **Fig. 5**). Based on this observation, he suggested that birds might have evolved from theropod dinosaurs (see **Box 3**).

However, this theory soon fell out of favour, particularly with the publication of an influential book, in 1926, by the Danish anatomist Gerhard Heilman. Through a detailed comparative analysis of the skeletal features of birds and other closely related groups, Heilman concluded that birds are more closely related to

Box 3. How did Darwin explain the evolution of new species?

According to Darwin's theory of evolution, new species arise due to a process of gradual change and continuous selection. Individuals in a population always differ from each other in many small ways — this is called **variation**. Variations arise because of differences in the genetic makeup of individuals.

When environmental conditions change, individuals with certain traits or genetic makeup have a better chance of survival. These individuals are also, therefore, more likely to reproduce and pass their genes onto the next generation. As a result, some traits become more and more prevalent as generations go by. With time, populations which accumulate a number of such unique traits may change to an extent that they can no longer mate with other populations of the same species. This is known as **reproductive isolation**. Coupled with the slow accumulation of different traits, it can lead to the formation of a completely new species.

Therefore, when we try to reconstruct the evolutionary history of a species, we often look at which other species or groups it shares the most similarities with. The assumption is that two similar groups must have had a common ancestor at some point in the recent past. A population of this ancestral species split at some point since then and slowly accumulating changes, over millions of years, gave birth to two completely different species.

Fig. 5. (a) An artist's reconstruction of Utahraptor, a theropod dinosaur. (b) Cast of a theropod dinosaur footprint from the Moenave Formation, Utah, on display at the BYU Museum of Paleontology.

theropod dinosaurs than any other group of animals. However, certain anatomical differences, particularly the presence of a fused collarbone in birds but absent in dinosaurs, make it impossible for the former to have evolved from the latter. Instead, he suggested that birds and dinosaurs may have evolved from a common ancestor called **thecodont**. So popular was this theory (and this book) that, over the next half a century, the 'thecodont hypothesis' came to be accepted by almost every expert in the field.

It was only in the late 1970s when a convergence of evidence from multiple sources resurrected the dinosaur → bird theory. Along with anatomical and fossil-based studies, the new science of cladistics (in which organisms are classified into groups based on how recently they shared a common ancestor) played a big role in this resurrection. Today, the dinosaurian origins of birds, and hence their status as 'living dinosaurs' is widely accepted.[1]

What was the evidence that cinched the deal? Fossils from many sources, particularly from the Jehol Biota of China, showed that early birds and certain groups of theropod dinosaurs shared many features. These include characteristics that we assume as being peculiar to modern birds, and that differentiate them from almost all other groups of animals living today. Examples of such features include feathers, wishbones, egg-brooding, two-legged walking, and even flight (see **Box 4**).

Let's take feathers, for instance. Bird feathers are complex structures that help in the aerodynamics of flight. They also help perform a number of other functions, such as maintaining body heat, egg-brooding, and attracting mates. Some fossils of early theropod dinosaurs show hair-like filaments that can be called **protofeathers**. Later theropods appeared to have feathers whose structures are much more similar to those of birds. Interestingly, as many fossil studies have shown, many non-bird dinosaurs were also covered in feathers. Feathered wings may have helped some of these, like microraptors (four-winged dinosaurs covered with feathers that are virtually indistinguishable from the feathers of modern birds), glide expertly (see **Fig. 6**). In other (clearly non-flying) dinosaurs, feathers may have served a completely different function. All of these point towards the idea that feathers probably evolved for a function other than flight — perhaps these colourful plumages were used to attract mates, or scare predators and competitors. Only later were they co-opted into helping the animal fly, and became specialized for the purpose.

Apart from feathers, birds have extraordinary sensory capabilities. These are helped by a large forebrain, which aids them in the rapid sensory processing and decision-making required for flight. Scientists have found evidence that some dinosaurian ancestors of birds also had largish forebrains, suggesting that their brains had already started achieving a state that would allow them to eventually evolve flight (in a sense, becoming "flight-ready"). Birds also have a rapid metabolism, which supplies the massive amount of energy required for flight. While reptiles are cold-blooded, birds are not; and evidence suggests that dinosaurs may have fallen somewhere between the two in the spectrum (see **Box 5**).

Fig. 6a. An artist's rendition of a pair of microraptors searching the forest of Liaoning in spring.
Credits: Durbed, Wikimedia Commons. URL: https://commons.wikimedia.org/wiki/File:Microraptor_by_durbed.jpg. License: CC-BY-SA.

Fig. 6b. **A fossil of *Microraptor gui* (scale bar at 5 cm) showing the preserved feathers (white arrow) and the 'halo' around the specimen where they appear to be absent (black arrows).**
Credits: David W. E. Hone, Helmut Tischlinger, Xing Xu, & Fucheng Zhang, Wikimedia Commons. URL: https://commons.wikimedia.org/wiki/File:Microraptor_gui_holotype.png. License: CC-BY.

The first true birds appear in the fossil record around 150 million years ago, about 85 million years before the Chicxulub collision (see **Box 6**). Scientists often have difficulty distinguishing the fossils of these early birds from non-bird dinosaurs, showing how similar the two branches could sometimes

Box 4. What makes birds special?

Many of the features that we consider to be unique to birds are in fact not so unique. Apart from a few flightless cousins, most birds can fly – but so can bats, and many species of insects. Birds have hard beaks which they use for feeding, nest-building, and a variety of other tasks. But beaks are also present in certain turtles, and even mammals like the duck-billed platypus. Egg-laying is also not specific to birds, as most fish and reptiles also bring forth their young in this way.

What, then, are the unique features of birds? The first and most obvious of these are feathers. No other currently living group of animals possesses true feathers. Bird feathers serve a variety of functions – they help in flight, insulation, and ornamentation. Interestingly, while this feature is considered unique to birds today, it wasn't always so – feathers have been found on both bird-like and non-bird dinosaurs.

Other, less obvious, features that are unique to birds include bones that are lightweight and hollow to aid flight, and egg brooding. However, egg brooding (which involves incubating eggs, and providing them with body heat) is arguably also seen in certain reptiles and amphibians, as well as egg-laying mammals like the Platypus.

be (see **Box 7**). The early forefathers of birds coexisted alongside their dinosaur brothers for nearly 100 million years, with small gradually accumulating changes distinguishing them from each other. The closest relatives of birds at the time were the small-bodied, feathered, large-brained dromaeosaurids and troodontids – theropod dinosaurs that resembled birds almost more than they resembled other dinosaurs (see **Fig. 7**).

Box 5. Teachers toolkit – learning comparative anatomy:

1. Divide students into two groups – Birds and Dinosaurs.
2. Encourage the 'Bird group' to research and list features they find unique and interesting in birds, and the 'Dinosaur group' to do the same for dinosaurs.
3. Invite students to present and compare the two lists to pick up on similarities and differences.

Surviving apocalypse

All of this gives rise to the question – how **did** birds survive the mega-extinction event that marked the end of the age of the dinosaurs? Well, our first clue lies in the fact that not all birds did. Most bird species did go extinct in the aftermath of the Chicxulub impact, and only a tiny fraction survived. We can only speculate on what marked this handful of species for survival.

A recent hypothesis suggests that the surviving branches of the bird-family consisted of birds that had evolved hard beaks, specialized to feed on grains or seeds, to replace jaws and teeth.[2] While much of plant foliage, fruits, and small prey would have been destroyed in the aftermath of the impact, seeds are much hardier. Their ability to feed on seeds may have been the one factor that tipped the scale in favour of these birds, protecting them from death by starvation. However, some scientists have disputed this hypothesis based on the existence of some toothed and beakless ancestors of birds that were also known to have fed on seeds. In addition, this hypothesis doesn't explain why certain species of beaked birds (especially small ones) appeared more likely to survive than others.

Box 6. How do we know the age of fossils?

While finding a fossil can be exciting for the amateur palaeontologist, figuring out exactly how old it is can be a tricky process. Scientists determine the age of fossils by two main methods – relative dating and absolute dating. In relative dating, fossils are compared to something whose age is already known, for example, the rock layer in which it was found. In absolute dating, scientists use trace amounts of radioactive minerals in the fossil, or (more commonly) its surrounding rocks, to determine its approximate age.

Fig. 7a. A large, short-armed, winged dromaeosaurid from the Early Cretaceous of China indicating the presence of feathers.

Credits: Junchang Lü & Stephen L. Brusatte, Wikimedia Commons. URL: https://commons.wikimedia.org/wiki/File:Zhenyuanlong.jpg. License: CC-BY.

Fig. 7b. Cast of the fossil dromaeosaur specimen NGMC 91 (nicknamed "Dave", cf. Sinornithosaurus) at the American Museum of Natural History in New York, showing early bird-like features.

Credits: Dinoguy2, Wikimedia Commons. URL: https://commons.wikimedia.org/wiki/File:Sinornithosaurus_Dave_NGMC91.jpg. License: CC-BY-SA.

Box 7. Teachers toolkit — understanding evolutionary distance:

1. Create a randomized set of about twenty to thirty anatomical features (e.g. long tail, five fingers, blue feathers etc.)
2. Print four copies of each of these features on small index cards.
3. Divide students into 5-10 small groups, and have each group draw five cards from the pack.
4. Encourage students to use their cards and the features printed on them to create an imaginary animal and name it whatever they like.
5. Invite students to compare the features of the different imaginary animals to figure out how closely related they are to each other.
6. Get students to create an evolutionary tree to connect their animals.

Another hypothesis contends that it is the habitat that these early birds were adapted to live in that made the biggest difference to their survival.[3] There is evidence of massive global deforestation occurring in the aftermath of the Chicxulub impact — the initial shockwave is itself estimated to have flattened all trees within a 1500 km radius. For a long time afterwards, dust and minerals released by the impact would have blocked out photosynthesis and resulted in frequent acid rains. When we consider these factors, it seems likely that tree-dwelling creatures would have swiftly run out of luck. The only birds to survive this period were much like today's chicken and other fowl — ground-dwelling, and small in size.

Parting thoughts

While it is still unclear how birds managed to survive the Chicxulub impact, today they are one of the most successful groups of animals on the planet. With more than 10,000 different species, birds have colonized almost every habitat on earth. Their powerful flight muscles allow them to soar for thousands of kilometres and, sometimes, at a height of over 9000 m above sea level.

So the next time you look out of the window and observe a crow scowling at you, remember that its ancestors once ruled the earth and, somewhere in its genes, the same majesty lives on.

Key takeaways

- A few families survived the catastrophic asteroid impact that led to the extinction of most dinosaurs.
- Birds are the natural descendants of theropods — a branch of one of these surviving dinosaur families.
- The survival of theropods may be linked to their ability to eat seed-like food (that was more abundant in the aftermath of the impact).
- Theropod ancestors of birds may also have survived the asteroid impact because they were small in size, and ground-dwelling rather than tree-living (trees were decimated by the asteroid impact).
- Many of the features we associate with birds today, like flight or feathers, were already present in their dinosaurian ancestors.

References:

1. Brusatte, S. L., O'Connor, J. K., & Jarvis, E. D. (2015, October 5). The origin and diversification of birds. Current Biology. Cell Press.
2. Larson, D. W., Brown, C. M., & Evans, D. C. (2016). Dental disparity and ecological stability in bird-like dinosaurs prior to the end-cretaceous mass extinction. Current Biology, 26(10), 1325–1333.
3. Field, D. J., Bercovici, A., Berv, J. S., Dunn, R., Fastovsky, D. E., Lyson, T. R., & Gauthier, J. A. (2018). Early Evolution of Modern Birds Structured by Global Forest Collapse at the End-Cretaceous Mass Extinction. Current Biology, 28(11), 1825-1831.e2.

Shreya Ghosh is a science writer and editor for IndiaBioscience. She can be contacted at shreya@indiabioscience.org.