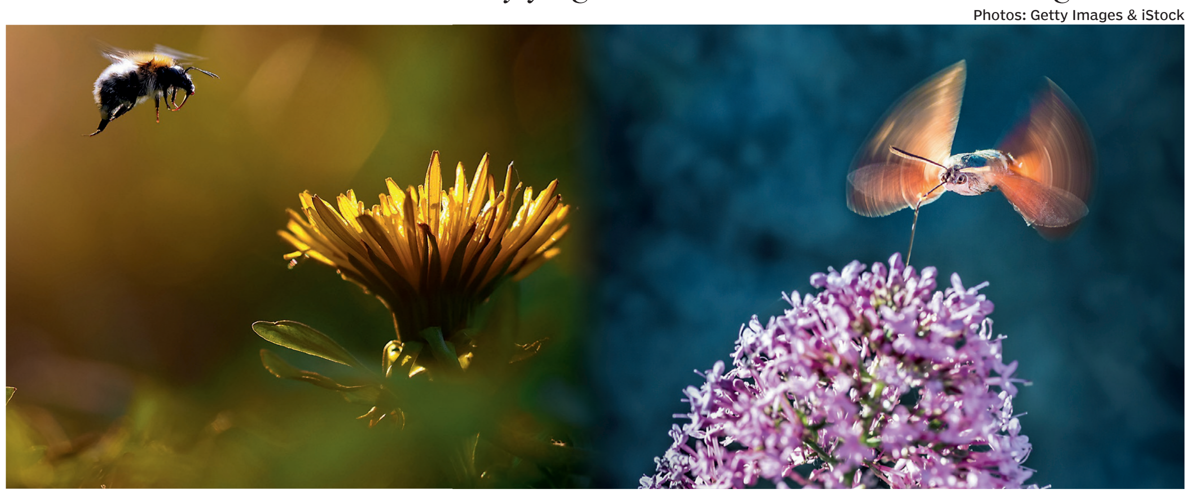
‘The wings of huge pterosaurs and tiny bees differ — but they both produce thrust and lift’

*Scientist **David E. Alexander** has researched ecology and evolutionary biology at the University of Kansas. Speaking to **Srijana Mitra Das** at **Times Evoke**, he discusses flying creatures — and how their wings work:*

Photos: Getty Images & iStock



NATURE’S FARMERS: Winged pollinators like bees (L) and the hummingbird hawk-moth (R) appeared hundreds of millions of years ago on Earth — their interactions with flowering plants generate a profusion of crops, enabling human life on the planet

Which species evolved the ability to fly?

■ The animals which developed flying under power — which means they can stay up doing so — are birds, insects, bats and pterosaurs or relatives of dinosaurs.

Many animals besides these can glide — there are fish that can glide in air, squirrels which glide between trees, etc. Aerodynamically, they are also flying but they cannot stay up. The only ones who can stay up as long as they want to have the power of flight — they flap their wings for this power.

Why did these species develop flight?

■ We can’t pin it down to one reason but if you think about all the advantages you gain from flight, these include a lot. For an insect, for instance, flight gives the ability to reach and colonise new habitats you couldn’t get to by walking. After the eruption of the Mount St. Helens volcano in Washington state in 1980, the first animals to appear afterwards were insects — they could easily fly in and reach the area which was otherwise totally covered in ash. There are several advantages flight bestows, from foraging abilities — if you’re searching for food, you can see much farther and cover more area while flying — to escaping predators.

Flying is also an energetically economical way to move large distances — consider how a species might gain by moving from a temperate region to tropical lands seasonally. They cannot achieve this by walking but flying enables birds to migrate whenever needed. The longest terrestrial migration by foot is around 400 kilometres — a typical bird migration is thousands of kilometres.

What is the planetary timeline for the evolution of wings?

■ First, insects evolved flight in the Carboniferous era which occurred about 300 million years ago. Quite a while later, pterosaurs did so in the Jurassic era about 145 million years ago. Birds came not too long after — they were there in the Cretaceous era 100 million years ago. And bats evolved flight fairly soon after the dinosaurs vanished. Of course, bats have very fragile skeletons which matters in the fossil record. However, we know they were flying about 50 million years ago.

LET’S TAKE OFF

What are fundamental operating principles of wings?

■ The basic work any wing must do is convert a forward movement into an upward force — this is true from a bumblebee to a jet airliner. By moving through the air due to its shape and the speed of moving, a wing produces an upward force. If you are a flying animal, the wing also has to produce a force that moves you forward — in an airplane, an engine separate from the wings moves the plane forward. As a bird or bee though, your wings must do both — this explains flapping. Airplanes don’t flap their wings because they have engines providing thrust to move ahead — flying animals produce thrust by flapping their wings. This moves them ahead and that movement then lets them produce lift. So, in a sense, a bird wing is not fundamentally different from an airplane’s because they both have to produce lift — yet, they are very different because a bird wing has to produce both lift and thrust. In some ways, a bird wing is more like a helicopter or propeller rotor since these also produce lift and thrust simultaneously.

Are there similarities between the wings of an insect and a dinosaur?

■ Structurally, there are about as different as you can imagine — an insect wing is structured around a series of veins, not as in blood vessels but cylindrical structures. A very thin, almost microscopically thin, membrane stretches between these. An insect wing is one of the lightest physical structures in nature which is also weight-supporting.

A bird wing is built around a modified front leg — so, it has bones, muscles and skin. A bird wing also has feathers over most of its surface. A bat or pterosaur wing would have stretched skin over most of its surface, a framework of bone and muscles. So, these are all extremely different — yet, if you look at the flapping mechanism between, say, a dragonfly and a bird, the pattern is not that different. Physically, the wing of both must flap to produce thrust and lift. They do the same physical thing with a structure that could not be more different.

Could you tell us about some fantastic wings you’ve come across?

■ An interesting one is the wing formed by the hind leg of a bird-like dinosaur called Microraptor — some palaeontologist colleagues of mine contacted me when they had these fossils. These dinosaurs were somewhat smaller than a cat and in the fossils we observed, there were long feathers on both their front and hind legs. We did tests to figure out how these feathered hind legs could work — we found they had operated as wings. It was basically a four-winged flyer.

A TWIST & A TERN: The river tern’s wings help it hunt

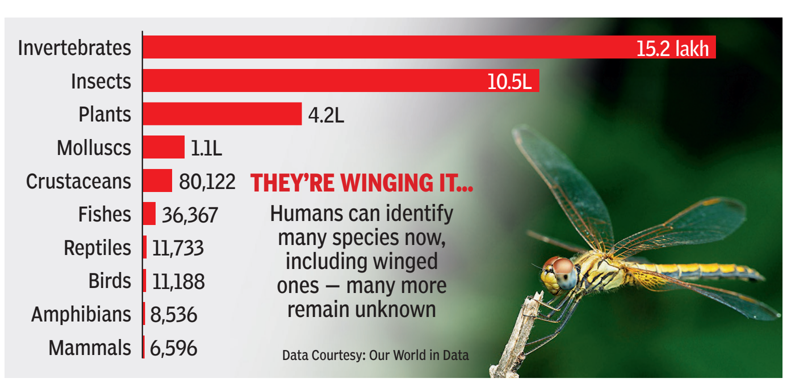
Other remarkable examples includes the largest pterosaur named Quetzalcoatlus northropi. By scaling up the bones at hand, it was found its wing was longer than that of a small airplane. In addition, some birds have very elaborate feather arrangements on their wings, some trailing behind them like streamers, some using these for making sounds in courtship displays.

Why should humans be more observant of winged creatures?

■ Engineers would say they have been around for millions of years and they may have solved major aerodynamic problems. Labs around the world are now essentially mimicking insect flight to build drones which can be used for surveillance, etc. Different labs are putting together essentially synthetic insects. A big area in aerodynamics now is ‘morphing wing’ technology — this means a wing that can smoothly change shape, in some cases, even changing its area. This is exactly what bird and bat wings do. A lot of research is going into the aerodynamics of this alteration in order to apply this to airplanes.

Birds and insects are also very important as they give us multiple services which we often don’t even realise — many eat mosquitos, for instance, which otherwise carry harmful diseases. Many flying insects are pollinators and produce food crops we need. So, when birds and insects start to disappear, we should be concerned. Their vanishing suggests something we are doing is impacting them adversely and while it may not be obvious, they provide us a great deal of benefits and services — aside from the fact that they are really cool.

NEAT! An Oriental White Eye shakes it up



A WING — AND A PRAYER

We live in happy times for not only can we make reels, we can buy hydra-headed camera phones to shoot a salad from 40 different angles and post this on social media, provoking animation, discussion and, hopefully, outrage. But among these high-brow delights, there is still something we advanced Homo sapiens cannot do — fly. No matter how hard we evolve, there is one thing nature has kept from us — the power of wings. Yet, it has graciously bestowed this on insects, birds and bats, species few of us pause to look at.

However, we should consider this winged world — dragonflies buzzing like self-important courtiers just before the regal rain breaks, butterflies fluttering to the top of tall buildings, birds weaving in and out amongst sun-drenched clouds — for it is full of wonders. Consider its antiquity — the first insects bearing wings emerged 325 million years ago. Some dinosaurs started developing wings 250 million years ago. After an asteroid wiped out most dinosaurs, you, gentle reader (who emerged only two million years ago) might have wondered if the flying age had crashed — but 165 million years ago, birds started evolving, descendants of therapods, literally making the dino ‘soar’.

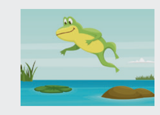
Today, Earth has 1,400 species of bats, 11,000 species of birds and over a million kinds of insects. Our planet’s collection of wings is mindboggling, from the diaphanous, gold-shot extensions of the dragonfly to butterflies richly decorated like frescoes and birds like the Griffon vulture with a wingspan over eight feet, flying 11,000 metres above sea level. These creatures are both magnificent — and munificent. Their activities, from pollinating plants to consuming pathogens and detritus, recycling nutrients and fertilising land, enable us to live. Globally, 87 of the 115 most used food crops rely on animal pollinators. They generate 35% of global food alone, gifting $577 billion to the world economy.

Yet, our lack of attention is now causing annihilation among these creatures. As we tear down forests to build more malls, use chemicals, lights and noise mindlessly, hunt and release invasive species, fewer creatures seem to be flying about us. UNEP estimates 40% of insect species have shrunk, facing extinction eight times faster than mammals. Scientists find humans have driven 12% of Earth’s bird species to extinction while pursuing even shy bats relentlessly enough to trigger zoonotic diseases. There are solutions though — as Times Evoke’s global experts emphasise, mindfulness is key. To preserve them, we need to look at winged creatures with greater knowledge — and awe. Join Times Evoke in exploring a world with wings — it could make your mind soar.

FREQUENT FLYERS

● Normally, we don’t envision fish in the sky — but **40 species of flying fish** exist! Found in warm oceans worldwide, these have wing-like fins — they first gain speed underwater. Angling up, the fish then breaks the surface, beating its tail, **leaping over 4 feet**. Certain fish have achieved **consecutive glides over 1,312 feet**, leaving predators agape far behind

● Frogs don’t just sit idly on lily leaves, watching the world go by — they jump to action! **Wallace’s flying frog**, found in rainforests in Malaysia and Borneo, mostly inhabits trees. Facing predators, it leaps, splaying its webbed feet — the membrane between the toes and skin-flaps on the side catch the air, **propelling the frog to glide across 50 feet or more**



● The shy **flying lemur** looks cuddly but it **can leap through the air over 230 feet without losing altitude**. Colugos, found in southeast Asia, have webbed feet and bat-like long limbs — when a lemur takes the plunge, its limbs stretch, controlling its glide, **one having ‘flown’ 490 feet** in a jump

Research: Encyclopaedia Britannica, IUCN, Smithsonian Magazine, BBC, National Geographic

Photos: iStock & Getty Images

MAGICAL MOTHS

● **Butterflies** get rave reviews for their **fabulous wings** — but **moths can easily outshine them.** Outnumbering butterfly species 10 to 1, there are **1,60,000 known moths in the world.** The **Atlas moth is one of the largest lepidopterans** or winged insects — found in tropical forests across **Southeast Asia**, its wingspan is **24 cms.** It’s also called a ‘snake’s head’ owing to the **cobra-like pattern on its wings**, scaring off pesky predators

● The **Luna moth** is a **superhero** — it **scatters bat sonar.** The luna of **north America sports pale-green wings** which blend into foliage — it also has **streaming tails that double its length.** Bats hunt using **sonar**, making high-pitched squeaks, following the **rebounding echoes** of beating wings — but the luna’s tails produce echoes, confusing bats. Even when they find a luna, they go for the tail, with **96% attacks foiled**

● The **rosy maple moth** is among **the world’s prettiest insects — smallest among silk moths** at just 4 cms, it is **pink and yellow**, its fuzz helping it pollinate better. Found in **north America’s deciduous forests**, it baffles scientists — its candy-like shades could be a **warning** about it possibly being poisonous or, less alarmingly, **clever camouflage**, allowing it to blend into flowers

Research: National Geographic, WWF, Smithsonian Magazine

‘Modern bird wings first appeared in the archaeopteryx 145 million years ago — they haven’t changed much’

__Nick Longrich__ is Senior Lecturer in Life Sciences at the University of Bath. Speaking to __Times Evoke__, he discusses the rise of flight — among dinosaurs:

Photos: Getty Images & iStock

THEN & NOW: The archaeopteryx fossil (above), the first bird dating back 145 million years, was discovered in Germany in 1861 — showing a complete set of wings, it is not too different from birds seen today, like the Hoatzin (R)

It might seem challenging at first to muster up enthusiasm for strange flying creatures born many millions of years ago, some even rather menacing-looking — but palaeontologist Nick Longrich gets you there. He outlines his research in a musing voice, ‘I’m interested in macroevolution, the big picture of life. I study how complex adaptations developed and the role of rare and improbable events like mass extinctions and oceanic dispersal.’

Longrich challenges some of the established wisdom in his field. ‘A standard approach in evolutionary biology is that macroevolution is just lots of microevolution — I question that.’ Evolution didn’t just happen automatically and rhythmically, Longrich argues. ‘Over very long timescales, unusual things happened. The evolution of flight, for instance, occurred repeatedly but in the last half-billion years, it only happened four to five times.’ He describes the wonder that is flight. ‘It’s an amazing adaptation, given how birds are very successful beings, widespread, diverse and long-lived — but avian flight only evolved once. Some other things evolved flight, like bats, insects and certain snakes which went halfway.’ Even as you ponder the charms of flying snakes, Longrich continues, ‘But the avian evolution of flight was extremely rare. You needed the right adaptations, happening in the right order, the most suited environment, the right ecological niches. Everything had to come into alignment or it couldn’t happen — that involves improbability or unpredictability.’

JURASSIC ARK

Avian flight has its roots in the Jurassic era. Longrich describes, ‘First, there were probably just dinosaurs, jumping between branches. To stabilise themselves, they’d possibly have thrown their arms out on the side, like a sky diver. This would make them descend more slowly. Next, the integument, the feathers and skin, could have expanded to make larger surfaces which could control descent more effectively. We see an incipient version of this in squirrels actually which have some membrane on their arms. Evolution could then start elaborating with feathers.’

Dino feathers wouldn’t have looked too polished. ‘Initially, these would have been quite crude,’ Longrich explains, ‘Instead of bird feathers, these would have been more hair-like, meant mostly for insulation. But packed together, like the collected bristles of a paintbrush, they’d allow you to control descent and steer. As these grew bigger, species could generate enough lift to descend at an angle — so, you’re not just coming down, you’re doing so and going forward. Creatures would also develop control over landing — they’d have large structures on their tail to stabilise this, like an arrow’s flight. Squirrels have a big bushy tail — this is an aerodynamic stabiliser which prevents them from tumbling. Dinosaurs possibly also evolved a big bushy tail alongside gliding and finally flapping.’

Again, the chances of all this happening were slim. Longrich says, ‘Dinosaurs began by gliding between trees — then, one lineage evolved which could flap its wings. Dinosaurs likely experimented with flight more than once. A fossil found in China has gliding membranes but these are not like those of birds — this could have been an independent evolution which didn’t go further. While they experimented, only one lineage of dinosaurs got lucky.’

Longrich’s own research on the archaeopteryx has been path-breaking. ‘The archaeopteryx is an early bird,’ he describes, ‘It dates back 145 million years. The skeleton is similar to a dinosaur’s, almost like a non-avian Velociraptor, but smaller. This has very modern feathers. It has pointed wings, tail feathers and little feathers on the hind limbs that act like a pair of extra wings. It could flap its wings and fly,’ Longrich pauses, then emphasises, ‘Perhaps not very well but it could fly.’

He describes his study of the archaeopteryx fossil, ‘I wanted to reconstruct the wings in detail. So, I started to draw, tracing, barb by barb, every shaft and structure — I then realised much of the conventional reconstruction didn’t work. You had these series of feathers that alternate with the wing feathers. They were so regular. Why was every other feather displaced rather than just one or two? How did everything else about these wings look perfect? I found we were actually looking at two different series of feathers — one was the main wing feathers. The other was the coverts.’ You can hear Longrich’s amusement as he says, ‘When you sit down and draw something, it forces you to let the fossil talk, instead of superimposing your preconceptions on it.’

Birds began evolving from the mid-Jurassic period. The process was slow, taking time — millions of years — to get the right mutations. ‘Meanwhile,’ Longrich says, enthusiastically, ‘There was a big extinction event during the Triassic era and another in the later Jurassic. All those also caused diversifications. This is when we tend to see evolution being its most innovative — things start moving in the wake of a mass extinction. After the asteroid impact which wiped out most dinosaurs, bats started evolving. Then came mammals.’

As birds, the successors of dinosaurs, evolved, their wings diversified. ‘There is a huge range of wings now. Some, like the albatross, are very long. Duck wings are really short. Some are specialised for soaring, some for diving. Some are even used as weapons, certain plovers, for instance, having stabbing spurs on their wings while geese have knobs on theirs to punch with. With evolution,’ Longrich smiles gently, ‘One feature might develop for a certain purpose — but then, it turns out to be useful for something else as well.’ Yet, the basic arrangement of bird wings hasn’t changed in the last 100 million years. Longrich says, ‘There is something very close to a modern bird wing in the Jurassic archaeopteryx. The feathers are primitive but in a few more million years, you’d have had basically a modern bird wing. So, a bird wing today is actually a living fossil — it hasn’t changed much. That’s also since it is as good as it can be.’

I CAN DO IT TOO! Squirrels can achieve some flight with their arms and bushy tail

I’M ACTUALLY PERFECT: Being superb, bird wings have not altered much over 145 million years

READERS WRITE

Dear Times Evoke,

It was wonderful reading about how elephants communicate (7th September) and to hear about Koshik, the elephant who can mimic human sounds! Elephants are very calm, quiet creatures and their gentleness always attracts humans. We TE readers really enjoy learning such amazing facts. Thanks a lot for this beautiful article, TE!

— **Priyanka Hirve**, Pune

It was fabulous to read about elephant communication. Through Angela Stroder’s expert insights, we could understand elephants also communicate through ear flaps, trunk-lifts and head-raising and they are not too comfortable when moved out of their habitats. Thank you for excellent information, TE!

— **S. Sankaranarayanan**, Chennai

I am 12 years old and I always rush to read TE every Saturday. TE enhances our awareness and today, reading about elephants, I started to understand that it is not just about saving animal species — rather, preserving our entire environment is critical in our struggle against global warming. Thank you, TE!

— **Nishka Agarwal**, Pune

I’m a first-time reader of TE and I wonder how I’ve missed such an informative feature for so long! The interview with scientist Angela Stoeger was excellent. It truly took me deeper into the magical world of gentle elephants. I simply won’t miss TE in TOI anymore! Keep up the amazing work!

— **BS Rawat**, Delhi

Thank you for the insightful discussion with Angela Stoeger. The article looked amazing and Stoeger clearly described diverse communications elephants use and her team’s research methods. It was great to learn these facts during the Ganesha Chaturthi holidays. Thank you for the wonderful feature, TE!

— **Sairam**, Ponneri

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