

Dinosaurs Take Flight Activity Facilitation Guide

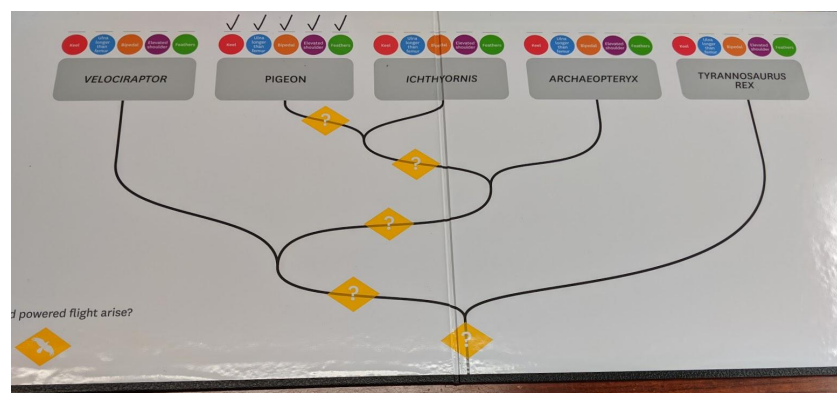
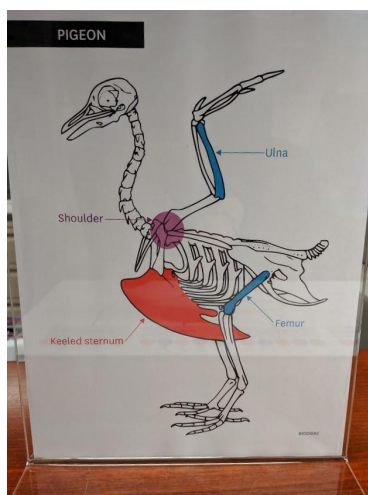
Cart or Table Activity

Materials and Set-Up

MATERIALS:

- Pigeon skeleton diagram
- Fossil evidence from 4 species in the bird lineage (*Ichthyornis*, *Archaeopteryx*, *Velociraptor*, *T. rex*.)
- Board
- Dry erase pen
- Dry erase marker
- Ruler
- Models of all 5 animals
- Bird flight token

SET-UP:



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Activity Goal

Visitors examine fossil evidence from the bird/dinosaur lineage and hypothesize where along that lineage flight evolved.

Activity Summary

Visitors work together using fossil evidence to explore how features of powered flight evolved over time. They make observations of features across 5 different dinosaurs/birds and use those observations to make hypotheses about where on the lineage powered flight evolved. In the process they explore how features that served non-flight purposes when they first appeared, were co-opted to aid in flight (exaptations).

Learning Objective: What visitors think, feel and do during the activity

In the course of doing this activity, visitors will:

- Make observations of, describe and compare flight features among theropod dinosaurs and their relatives
- Use an evolutionary tree to make hypotheses about the origins of flight in dinosaurs
- Discuss, explain, and debate with family members to make observations and explain their reasoning when making hypotheses
- Feel like they are doing science

**Learning Outcomes:
New understandings or changes in perspective that result from activity**

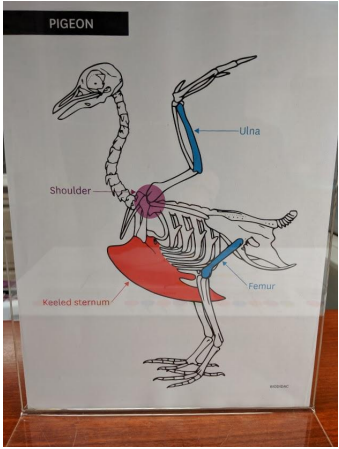
We anticipate visitors who participate in this activity are more likely to:

- Understand that paleontologists use modern examples to extrapolate from evidence they find in the past.
- Better understand that evolutionary development of new traits and behavior among living things does not happen in a stepwise or intentional way, but is the result of nonlinear mechanisms like exaptation
- Better understand that different types of unrelated animals develop similar traits to live in similar environments - convergent evolution
- Better understand how to read evolutionary trees and why and how scientists use them to represent hypotheses about relatedness, to explore and generate questions about evolution of traits, and to represent shared features among living things.
- Feel more comfortable and confident engaging with science, independently and as a group or family.

Target Audience

Families with children 8-12, but adaptable for all.

Activity Flow

What to say	What to do
<p>HOOK [INSERT YOUR OWN HERE]</p>	<p>⇒ Differentiate according to audience</p> <p>⇒ Pigeon diagram is on the table</p>
<p>INTRODUCTION [REFERENCING THE PIGEON DIAGRAM]:</p> <p><i>Do you know what this is? That's right; it's a diagram of a bird skeleton. In fact, it's the skeleton of a pigeon. What makes birds special? What are they able to do that humans can't?</i></p> <p><i>Right. They can fly. And today we're going to look at how they fly and when in their evolutionary history those different features appeared.</i></p>	<p>⇒ Pigeon diagram is on the table:</p> 
<p>GUIDED PARTICIPATION <i>Bird Flight Anatomy</i></p> <p><i>What do birds have that allow them to fly?</i></p> <p>[WAIT FOR RESPONSES]</p>	<p>⇒ Pigeon diagram is on the table:</p>

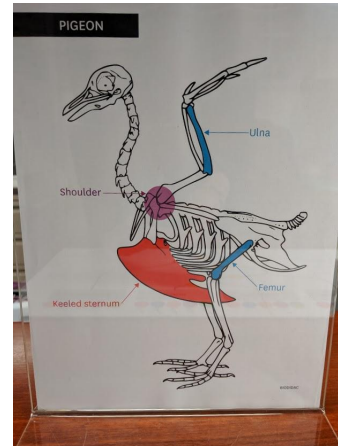
Yes, they have feathers and wings. If we look at this skeleton there are some other important features that help them fly.

They use their arms as wings, so what does that mean about how they walk? Right, they walk on two legs. They're bipedal.

Now, let's think about the motion needed to get a bird up into the air. They need big muscles for that upward motion and the downward motion. When animals have big muscles, those muscles need big places to attach on the skeleton. So birds have this keel. You can see it sometimes when you cut into a chicken.

The wings have to be long, so that means their arms have adapted over time to be as long or longer than their legs. And their shoulders have to be in a special position. If you lean forward and try to align your shoulders like a bird, then lift your arms up over your head, what happens? Give it a try.

But if we look at the bird, see where the shoulder is here? It's elevated.



⇒ Model this for them. Lean forward yourself and try to raise your arms. Try to get the whole group to do this.

So to review, key features we've identified: feathers, two legs, a keel, long arms, elevated shoulder.

Evolution Intro

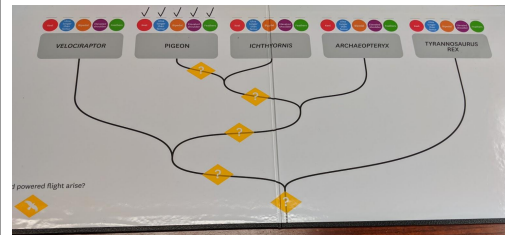
Now, scientists now know that birds are dinosaurs, right? They're from the lineage of theropod dinosaurs that include Velociraptor and T. rex.

So here we have a family tree of some of these birds and bird relatives.

This tree is a diagram that scientists use to show evolutionary relationships, relationships of living things through time.

This tree represents living things evolving. As you go up the tree, branches represent independent lineages evolving into new species. These new species share most characteristics with their common ancestor, but have acquired new features as well that make them distinct. Species with the most number of characteristics in common are the most closely related, and therefore likely had similar lifestyles. Species that branch off close to the base of the tree

⇒ Bring out the tree board:



⇒ Point out the different animals.

share fewer characters with species that branch off close to the top.

And we can use this tree to work out where in this lineage flight evolved.

So we saw these traits are important for modern birds to fly, we can look for these traits in the fossil record in theropods.

You all are going to use fossil evidence to answer the question--when on the bird lineage did powered flight evolve?

Traits and Tree Work

I'd like one of you to be the lead researcher, and the rest of you will be field researchers in charge of telling the lead researcher about one of these species.

You can see here for the pigeon that we have checked that it is bipedal, it has a keel, it has feathers, it has an elevated shoulder, and it has long arms, which we measure by comparing the length of the ulna with the length of the femur.

Now, you can work together and check which of these features you can look for evidence and

⇒ Point to the pigeon square and the traits listed above.

⇒ Give the lead researcher the marker.

⇒ Give one of the bird relatives to different field researchers:



make observations in your different fossils. You can use a question mark if you're not sure.

**[LET THEM WORK IT OUT TOGETHER;
GUIDE IN A LIGHT WAY ONLY AS NEEDED
TO KEEP THEM ON TRACK]**

⇒ Now let them work it out, but listen for these places where they are likely to get STUCK, and encourage them to use question marks. These are opportunities for scientific discussion:

- *Ichthyornis* Feathers: There is no direct evidence of feathers in the *Ichthyornis* case, but because we see that relatives on either side had feathers, scientists think *Ichthyornis* probably did too.
- *Archaeopteryx* Elevated shoulders: Have them compare the location of the shoulder with velociraptor, which obviously isn't elevated. Is it more like a pigeon or more like velociraptor?

Ok. How do you feel? Let's check to see where you had question marks.

We know that modern birds use all of these features in flight. Which other bird-relative has all of these characters? Which ones have fewer?

Given all this evidence--where on the tree do you think flight evolved? Remember, if multiple species share a feature, the lineage including their common ancestor also had it.

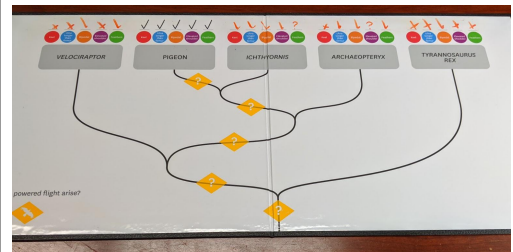
Discussion

What is surprising or interesting about your findings?

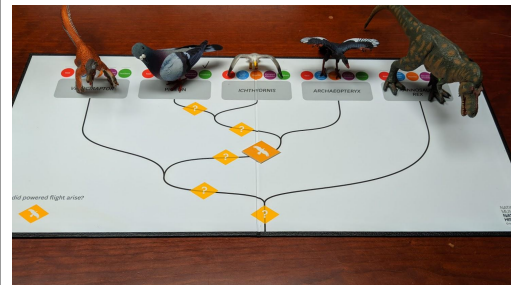
What about Velociraptor? Why does it have feathers? What does that tell you? Why would it have had feathers if it couldn't fly?

[ACKNOWLEDGE GOOD THINKING]

Feathers are an example of exaptation. They served different functions or were just there before powered flight evolved. They were co-opted and together with other key traits allowed some dinosaurs to fly and take advantage of entirely new ecosystems (better word)?



⇒ You can bring out models to have this conversation:



⇒ You can discuss convergent evolution pointing to pterosaurs if there's interest.

WRAP UP/RELEASE

[INSERT YOUR OWN HERE]

⇒ Identify the science skills the visitor used in the activity.

⇒ Direct them to other parts of the museum or elsewhere for related content.

Background Information

Evolution of Bird Lineage

Although the K-Pg event is well known for resulting in the extinction of the dinosaurs, paleontological discoveries over the past few decades have revealed that we shouldn't mourn their loss entirely! While it is true that many of the iconic dinosaurs such as *Triceratops* and *Tyrannosaurus* went extinct after the Cretaceous, some of their relatives were able to survive this calamity. These survivors are birds. At first glance, it may be hard to see how these small feathered creatures could possibly be related to something as large and fearsome as a *Tyrannosaurus*, but if we take a closer look in the fossil record, we can start to see that birds are in fact living dinosaurs!

Today's birds are part of a group of dinosaurs known as **theropods**. Theropods include bipedal carnivorous dinosaurs such as the well-known *T. rex*, *Allosaurus*, and *Velociraptor*. These non-avian dinosaurs bear many skeletal features that can be found in today's birds, such as hollow bones, a strap-like scapula (shoulder bone), and fused clavicles that form a **furcula**. The furcula is the wishbone that you find when carving a chicken or turkey, and this feature is unique to theropods! Today the furcula is only found in birds, so the presence of a furcula in many non-avian theropod dinosaurs is a clear sign of their evolutionary relationship!

There are several examples in the fossil record that give us further indications of the connection between non-avian dinosaurs and the avian theropods that we know as birds, but perhaps the most famous example is *Archaeopteryx*. *Archaeopteryx* lived during the Late Jurassic (~150 mya) and displays an incredible blend of features that reveals it to be a transitional form between non-avian dinosaurs and modern birds. Like the non-avian theropods, *Archaeopteryx* had a full set of teeth, a long tail, and a series of ribs along its belly (**gastralia**). One of the most amazing bird-like features found in *Archaeopteryx* fossils is the clear presence of feathers covering their bodies. Over the years, many examples of feathered non-avian dinosaurs have been found as well, including a 99-million-year-old feathered dinosaur tail preserved in amber!³

Exaptation

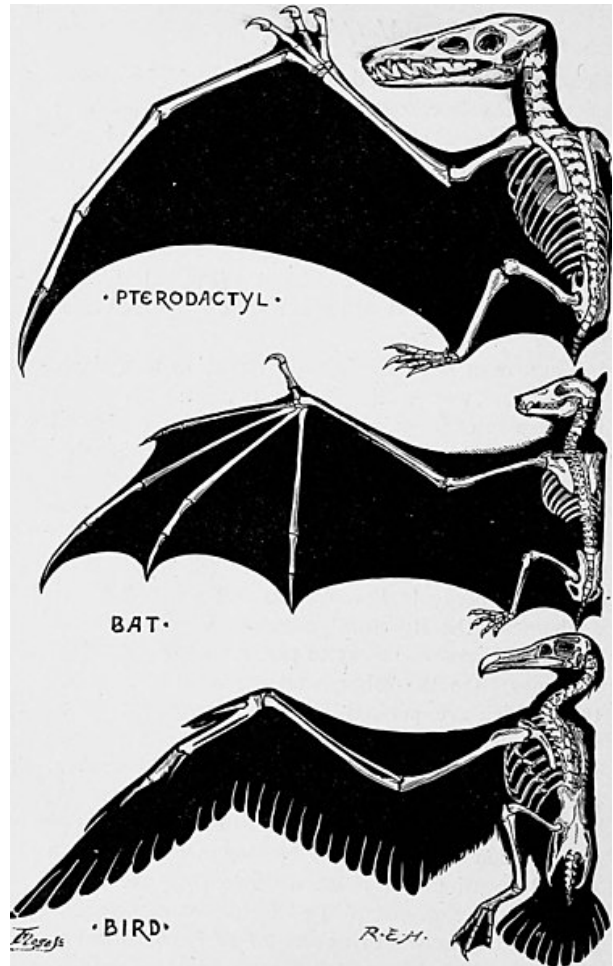
Today birds use their feathers largely as a way to achieve flight. Their curved, lightweight feathers help them to generate lift that allows them to become airborne. However, flightless birds such as ostriches are also covered in feathers. If these birds aren't able to fly, why do they have feathers? This is because feathers are an example of an **exaptation** for flight. An exaptation is a trait that may serve a particular function now, but this was not the original usage that this trait was naturally selected for. When feathers first evolved, they were small, downy feathers that likely served primarily to provide insulation. This is why we see examples of feathered non-avian theropods in the Mesozoic fossil record despite their inability to fly. Over time, feathers became utilized for a variety of other purposes such as mating and territorial displays and, of course, flight.

Convergent Evolution - Evolution of flight in vertebrates

The ability to fly is one that we strongly associate with birds, but they are certainly not the only animals that have taken to the skies! Bats also rely heavily on powered flight and in the Mesozoic fossil record we also encounter pterosaurs which are considered

the earliest vertebrates to have evolved powered flight. While all of these creatures share this remarkable ability, it's important to realize that this is not an indication of their relatedness to one another. Bats are mammals while birds are technically reptiles, and pterosaurs, though commonly mistaken for dinosaurs, are an entirely distinct group of flying reptiles.

Flight is not a feature that was passed down to each of these groups from a common ancestor, but rather one that evolved independently multiple times. This is known as **convergent evolution**. If we examine each of these animals more closely, we can see that although they each developed wings to power their flight, the structure of their wings varies incredibly. A bat's wing consists of a thin membrane that is spread across their highly elongated fingers. A pterosaur's wing also featured a membrane, but rather than being spread over multiple fingers as we see in bats, the pterosaur wing membrane was actually stretched across a single incredibly elongate fourth digit. Alternatively, a bird's wing is made up of feathers that are largely supported by an elongated **radius** and **ulna** (bones of the forearm). Unlike the long, thin fingers that we see in bats and pterosaurs, the bones making up the fingers of birds are greatly reduced and fused! These distinct structures tell us that these groups followed very different evolutionary paths to achieve flight.



Source:
<https://commons.wikimedia.org/wiki/File:Homology.jpg>

Species Blurbs

T. rex

Tyrannosaurus rex is of course one of the most famous dinosaurs of all time, well-known for its intimidating size and its large, powerful jaws. *T. rex* lived during the late Cretaceous, right before the K-Pg extinction, and it is one of the largest predators to have ever existed on land. This creature could reach up to 13 feet in height and over 40 feet in length with 8-inch-long serrated teeth, and it likely ranged between 11,000 and 15,500 pounds. Close relatives of *T. rex*, such as *Dilong paradoxus*, have been found to be covered in a thin layer of featherlike fibers, indicating that *T. rex* (or at least *T. rex* juveniles) were likely covered in a soft down as well!

Velociraptor

Velociraptor was most famously portrayed in the Jurassic Park film series as a vicious, highly intelligent hunter. While this animal was no doubt a ferocious carnivore, it is important to take time to separate movie magic from scientific evidence. While the *Velociraptors* in the films are depicted as 6-foot-tall beasts, these dinosaurs were actually no bigger than a turkey. Also, despite their scaly appearance in the series, evidence in the fossil record suggests that *Velociraptors* were feathered! In 2007 an article was published in Science Magazine revealing the discovery of quill knobs on the forearm bones of *Velociraptor*! We see these same knobs in many modern birds that show where their feathers are anchored to the bone, thus providing us with some particularly compelling evidence that these non-avian dinosaurs were feathered as well.

Archaeopteryx

Archaeopteryx is often considered to be the oldest known bird. This bird did not have a beak like today's birds, but rather had a full set of teeth similar to non-avian theropods. Despite its distinctly feathered wings, paleontologists have long debated this creature's ability to fly. Today's flying birds have a distinctly keeled sternum (chest bone) where

powerful flight muscles attach, but *Archaeopteryx* lacked this feature and instead does not preserve a bony sternum. While some have proposed that *Archaeopteryx*'s feathers only acted as insulators and others have claimed that it could only glide, currently it is thought that they were capable of short bursts of powered flight, similar to what we see in modern-day pheasants.

Ichthyornis

Ichthyornis was a bird from the Late Cretaceous which bore a resemblance to today's seabirds. This early bird is particularly interesting as its skull shows a distinct point in the transition between non-avian theropods and modern birds. Not only did this bird have a beak, but it had sharp, curved teeth as well! But, in all other respects, it was like a modern flying bird.

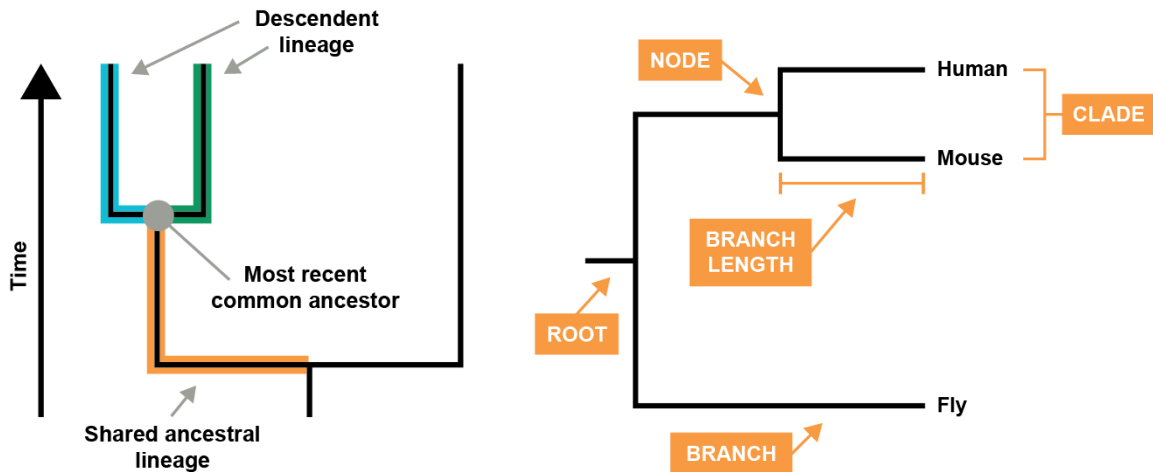
Pigeon

Pigeons are a perfect example of a modern-day avian dinosaur. They have several features that make them well adapted for flight such as hollow bones that make the skeleton lighter, a keeled sternum for attachment of strong flight muscles, and a furcula that helps to stabilize the body during flight. Unlike early birds such as *Archaeopteryx* and *Ichthyornis*, modern birds like pigeons do not have teeth, but they have a beak instead.

Evolutionary Tree Primer

One of the biggest challenges that paleontologists face is trying to understand the complex relationships between all organisms, whether living or extinct. One way we try to accomplish this is by constructing **evolutionary (phylogenetic) trees** that act as visual representations of our hypotheses of these interconnected relationships. Each **branch** represents a particular lineage and each branching point of a tree (**node**)

indicates the point where an ancestral lineage diverged into two distinct lineages. Therefore, each node represents the most recent common ancestor that is shared between all the groups following that node.



Illustrations by Jennifer Renteria, Smithsonian

To construct an evolutionary tree, we first need to determine the evolutionary relationships between each of our organisms by examining their shared heritable characteristics/traits. Organisms that share a greater number of traits with each other are likely more closely related. By making a checklist of which traits are present or absent in each of our organisms, we can determine which features likely evolved early in their ancestry and became passed down to each subsequent lineage, versus traits that evolved more recently and help to distinguish a separate lineage. Traits that evolved that differentiate new lineages from their ancestral groups are known as **derived** traits, whereas **ancestral** traits are those that are inherited from more distant ancestors.

References

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