



*Charlie and Kiwi's Evolutionary Adventure*  
A Descriptive Guide to the Exhibition Elements, *Story Theater* and  
Discovery Boxes as They Relate to Evolutionary Mechanisms

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## Introduction

The purpose of this guide is to acquaint the reader with the exciting traveling exhibition, *Charlie and Kiwi's Evolutionary Adventure*. The guide is meant to provide general information about the various exhibits, the Story Theater and the Discovery Boxes available within the exhibition. This guide, however, is primarily intended to serve as a brief resource that reflects how each element of the exhibition relates to evolution – particularly natural selection and the mechanisms that influence biological evolution. Written primarily for museum professionals, this guide is geared to serve educators/docents who have had exposure to secondary level science courses, although those that have little previous knowledge of science in general may utilize this guide. Further, although some technical terms are used, a glossary is provided to aid in understanding the meaning of those terms.

This guide is not meant to provide the reader with an overview of evolutionary biology or disciplines that lend themselves to the study of the field. For such knowledge, the reader is referred to *Understanding Evolution* located on the University of California, Berkeley's Museum of Paleontology website. The website address is <http://evolution.berkeley.edu>. Finally, a list of references used in composing this guide is also provided at the end of this guide should the reader seek further information or if he/she wishes to know the sources of information or illustrations provided in the guide.

## ***Charlie and Kiwi's Evolutionary Adventure: Exhibit Element Descriptions***

This section describes each element of the exhibits and how it relates to the process of biological evolution with particular reference to natural selection. In bold letters are the actual graphics as they appear in each exhibit. The description that follows gives specific information on each exhibit as it pertains to evolution and its governing mechanisms.

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### **EXHIBIT 1.**

#### **INTRO PANEL**

*See how life changes over time*

**Flamingos! Penguins! Robins! Eagles! They're all birds, but they look so different. Want to know why? Come travel back in time. Join Charlie and Kiwi on their *Evolutionary Adventure!* Explore Charlie's world, dive into a discovery box, watch the show and enjoy!**

This exhibition focuses on five major concepts in evolutionary biology that are encompassed in the acronym VISTA: Variation, Inheritance, Selection, Time and Adaptation. Throughout the exhibition, it will be seen that variation in traits occur in individuals of a kind or, species, that make up a population. Certain traits possessed by individuals provide those individuals with a selective advantage that allows them to survive within a given environment. This is known as an *adaptation* and as long as the environment does not change, a given adaptation will be passed onto the offspring of those individuals within the population who are fit, or, those individuals who survive long enough to reproduce and have their genes passed onto to the next generation of offspring. Over time, many generations of offspring will be produced, each with their own slight variations. These variations can add up, which in turn, could be so great that a new kind, or species, could develop.

In this exhibition, we focus on birds, the diversity of birds and the ancestors from which they arose to illustrate the process of evolution.

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### **EXHIBIT 2.**

**Which is a Bird? Which is a Dinosaur?**

**How can a ferocious dinosaur be related to *birds*? They seem completely different! Or... are they? Look at the bones!**

**The Bones Show It**

**Today's birds have many of the same bones found in meat-eating dinosaurs. So many, in fact, scientists are convinced that birds *came* from dinosaurs! See the evidence for yourself. Use the matching colors to find and compare the same bones in all three animals.**

This exhibit depicts *homologous skeletal structures* linking birds to saurichian dinosaurs. Homologous structures are those structures that are shared amongst descendents having a

common ancestor. Variation amongst offspring in subsequent generations is genetically passed down. However, over time and many generations, variations may occur such that descendants form distinct groups. The retention of homologous structures in descendants sharing a common ancestor demonstrates an evolutionary relationship between living things.

**Meat-eating dinosaur  
(75 million years ago)**

**This dinosaur, called *Bambiraptor*, had many birdlike bones. Wishbones are found only in birds and a few meat-eating dinosaurs. *Bambiraptor* caught prey with its sharp teeth and claws. Scientists think it might have had feathers. But it didn't have wings and could not fly**

The presence of a *wishbone* (or *furcula*) in birds and meat-eating dinosaurs such as *Bambiraptor* demonstrates that these creatures share a common evolutionary history. Although unable to fly due to a lack of wings, *Bambiraptor*, like both flying and flightless birds, possessed a furcula. The furcula helps secure bones, such as the sternum and the coracoid, to which the muscles employed for flight are attached. Flight, in itself does not suggest common ancestry and, indeed, the ability to fly has also evolved in insects and in mammals as well. These animals, however, lack the presence of a furcula, using other anatomical features to achieve flight. Nevertheless, the furcula, which lends itself to flight, is possessed by some dinosaurs as well as both flying and flightless birds thereby providing evidence for common ancestry amongst these two groups.

**Bones and colors of bones are:**

**Wishbone – coral**

**Arm bones – orange and yellow**

**Leg bones – dark blue and light blue**

**Pubic bone – green**

**Backwards-pointing toe – red**

**Anatomical features mentioned in text about dinosaurs, early birds and modern birds:**

**Dinosaur – wishbone**

**Early bird – teeth, long tail, claws, no hands, arms to wings**

**Modern bird – no teeth, no long tail, no fingers; breastbone and flying muscles**

**Early bird**

**(155 million years ago)**

**This prehistoric bird, *Archaeopteryx*, looked like something between a dinosaur and a bird. It had teeth, a long tail and claws like a dinosaur. But it didn't have hands. Instead, its "arms" formed wings that allowed it to fly.**

Displaying both avian and reptilian features, *Archaeopteryx* represents an example of a transitional form. It possessed claws and was capable of flight, both an adaptation for hunting prey and escaping from being preyed upon. Teeth and a long tail are demonstrative of reptilian traits yet feathers covering the body clearly represent a link in avian evolution. Feathers served for flight and thermoregulation and are analogous to the scales of reptiles. It should be noted that although there are several individual fossil specimens of *Archaeopteryx* these specimens represent individuals within a population. Thus the genes carrying reptilian and avian traits were present in the gene pools of *Archaeopteryx* populations.

### **Modern Bird**

**(Specimen from 2 Years Ago)**

**This crow is like all modern birds: it doesn't have teeth, a long tail or finger bones. The big breastbone anchors its flying muscles. Changes in the skeleton made it possible for birds to fly. But looking at the basic structure---can you see a dinosaur still hiding in the bones?**

**Wishbone, backwards-pointing toe, pubic bone, arm bones, leg bones, breastbone.**

Crows exhibit avian features while reflecting some reptilian traits, particularly in their skeletal anatomy. A large breastbone and wishbone are employed in the ability to fly while a backward-pointing toe allows for the ability of birds to remain stable upon resting on a perch. Although such features are present in reptiles, the same features serve as selective advantages throughout avian species. They enable modern birds, for example, to hunt, to escape predators and to roost. These adaptations could, consequently, lend themselves to increased biological fitness amongst individuals within bird populations leading to the propagation of traits throughout populations in both space and time.

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### **EXHIBIT 3.**

**Why is a kiwi like a kiwi? Of How Evolution Works**

**Did birds really come from BIG dinosaurs like this?**

**OR**

**Did birds really come from BIG four-legged dinosaurs?**

### **Flap 1**

**No! Only the small, meat-eating dinosaurs gave rise to birds. (The really BIG dinosaurs all died out.)**

There are numerous theories as to why the dinosaurs became extinct at the end of the Cretaceous Period 65 million years ago. Some scientists suggest changes in global climate. Some scientists suggest a meteorite impact. Some scientists think it was volcanism. It could also have been a combination of these factors. Whatever the cause or

causes, some dinosaurs had advantages that allowed them to survive and pass their genes onto their offspring. In this case, the meat-eating dinosaurs were best suited for their environment and had traits that we now recognize as being associated with reptiles and early birds. Eventually, the traits were so different that a whole new evolutionary line was established thus we have the emergence of birds and, later, the incredible diversity that we see amongst all birds.

## **Flap 2**

**How could a dinosaur evolve into a bird? They seem so different!**

**Little changes led to big changes---step by step, from one generation to the next, over a long, LONG, LOONG time.**

Dinosaurs did not simply “evolve into birds.” First, individual organisms do not evolve. Populations of organisms evolve. Secondly, some dinosaurs possessed traits that made them a little different from others within their populations. Over many generations, these traits were passed down to descendants who later exhibit traits that we now recognize as truly avian.

## **Flap 3**

**Is evolution like tadpoles changing into frogs?**

**No, not really. Evolution happens over many, many generations. Individuals don’t evolve---but over time, groups do.**

There is, indeed, a change when considering a tadpole developing into an adult frog. However, this is not evolution. During the life cycle of an organism (ontogeny) developmental changes do not constitute evolutionary change. There is no change in genetic make up and there is no inheritance of genes by offspring. Indeed, we are only considering an *individual* in such a case. However, if a *population* of frogs, once they reach maturity, begins to mate and spread their various genes throughout a population, in turn, giving rise to a subsequent population of frogs, the potential for new traits is possible. Over time, these traits can lead to traits so different, that a completely new form of frog develops. Further, if this new form is reproductively isolated from its ancestral form, we have the emergence of a new species. THIS is evolution!

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### **EXHIBIT 4.**

#### **The Clue of the Matching Bones**

**I know a secret. Birds evolved from dinosaurs! (They have three hidden bones that show it.)**

**Meat-eating dinosaurs**

**Early birds**

## Modern birds

**These three share similar bones**

**If different animals have the same bones, that's evidence they're related. Three special bones show scientists that birds evolved from dinosaurs. Only birds and a few two-legged dinosaurs have bones just like these.**

**Find Where the Matching Bones Go**



**The Wishbone: Chickens have them; so do dinosaurs.**

Meat-eating dinosaurs, early birds and modern chickens all possess a furcula, more commonly known as a wishbone. In meat-eating dinosaurs the exact function of the wishbone is uncertain and, in the past, it was argued as to whether or not the furcula could be considered a character linking birds to theropod dinosaurs. However, in recent years it has become an established fact that the furcula was, indeed, possessed by such meat-eating dinosaurs as *Oviraptor* and *Tyrannosaurus rex*. However, throughout avian evolution, the clavicles more commonly seen in theropods, were recognized to have become fused forming a furcula. Examples of this are seen in *Archaeopteryx* and modern birds, such as chickens. It is thought that the furcula aids in flight by securing the musculature involved in flying. It should also be noted that in flightless birds, a furcula is present although somewhat degenerated, lending further support to the furcula's role in flight.

**Toes: Four toes with one pointing backward.**

In examining the toes of meat-eating dinosaurs, early birds and modern birds, it can be seen that three toes extend forward and one backward. In dinosaurs, the arrangement of the toes allows for running, perhaps an adaptation for chasing prey or escaping predators. This overall form is retained in early arboreal birds (*Archaeopteryx*), however, there is slight re-curvedness of the claws; the feet of meat-eating dinosaurs display a more flat condition. In modern birds, the primitive condition of having three forward extending toes and one backward pointing toe can be seen. However, the curvature of the foot is much greater thus serving to support arboreal birds for tree dwelling. What is seen, is a gradual progression of a trait that is reflective of the ground dwelling habits of dinosaurs

but later retained, over the course of avian evolution, by early birds and later more advanced modern birds with variation reflecting form and function.

### **Hip: Pubic bone in the hip slants backward**

The presence of a pubic bone in the hip with a backward and slanted orientation is a key feature linking meat-eating dinosaurs, early birds and modern birds. Such an arrangement of the hips allows for bipedalism amongst members of this lineage. It is suggested that bipedalism may have aided in advances in feeding and locomotion. Regarding feeding, bipedalism allowed for the use of forelimbs to grasp prey, as forelimbs were no longer in use for walking. Further, forelimbs, over avian evolution, became specialized as wings and eventually aided in the development of flight.

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## **EXHIBIT 5.**

### **Finches Puzzle**

**These birds all evolved from one kind of finch. Look how different they are now! Each bird's adapted to eat different foods. Put them in the forest where they can find a meal.**

Each of the birds presented in this exhibit descended from an ancestral population of finches. During the evolution of the lineage that encompasses the finches presented in this exhibit, various traits arose that gave a selective advantage to each finch such that it can occupy a certain niche within its environment. For example, we see in the Akohekehe and I'iwi finches that curved beaks are an adaptation for sipping nectar from flowers and that in the Nuku-pu'u finch a slender beak provides a selective advantage such that the bird can pick insects from bark. In the ancestral finch population, there was some variation amongst the individuals comprising the population. Those individuals that had traits that enabled them to survive within their environments reproduced. The traits of these birds were then passed on to their offspring, giving rise to the various kinds of finches that we see presented.

**Akohekohe: This bird uses its curved beak to sip nectar from flowers.**

**Apoapane: This bird flits through the trees, searching for nectar in flowers.**

**I'iwi: This bird uses its curved beak to sip nectar from flowers.**

**Amakihi: This bird looks for insects down in the leaves and for nectar up in the trees.**

**Akeke'e: This bird searches for insects among the leaves.**

**Akepa: This bird eats grubs that live inside leaf buds.**

**Nuku pu'u: This bird uses its slender beak to pick insects from tree bark.**

**Parrotbill: This bird uses its strong beak to dig grubs from rotting wood.**

**Laysan finch: This bird's handy beak lets it eat almost anything: insects, seeds and many kinds of fruit.**

**Palila: This bird uses its strong beak to open seed pods high up in the trees. (says high in the trees, however, it is low near the ground)**

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## **EXHIBIT 6.**

### **Meet the Budgies**

**I love keeping budgies. Each one is different. See if you can tell my pet birds apart.**

**See if you have a good eye for birds. A cage of budgies is a colorful sight, full of blue, green or yellow birds with different spots and stripes. Each is an individual, different from the others. Some of the birds are easy to tell apart. Others are harder. Can you recognize each bird? Look for differences in...**

#### **Color**

**Throat spots**

**Stripe patterns**

**Size**

#### **Why do budgies come in so many colors?**

**Wild budgies are almost all green. People selected a few different-colored ones and bred them together to get more/many colors.**

Budgies are a commonly kept household pet bird. Although they all belong to one species, *Melopsittacus undulates*, there are many variations in the coloration, throat spots, stripe patterns and sizes of budgies. These variations in appearance are the result of artificial selection. Bird keepers who breed budgies select certain traits such as a particular type of coloration or stripe pattern within a parental stock which then produce offspring that exhibit a combination of traits which are inherited from their parents. These offspring may then be bred which may result in further genetic variation within the population. Note, that although there could be a number of variations, budgies of the same species can all reproduce with one another and produce viable offspring.

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## **EXHIBIT 7.**

**Dino to Bird computer-based interactive allows visitors to speed up time so they can see the evolution of birds happen with their own eyes**

### ***Bambiraptor* changing into *Archaeopteryx***

The first birds evolved from small, meat-eating dinosaurs. Like these dinosaurs, birds have hollow bones and walk upright on two legs with three-toed feet. The birds of the Jurassic had three-clawed hands and sharp teeth inherited from their dinosaur ancestors.

But birds are unique---they can fly. All birds share special adaptations that helped them fly. These adaptations make birds different from dinosaurs but they could easily have evolved from a dinosaur's anatomy.

Can you help this running dinosaur get off the ground by changing it into a Jurassic bird?

Look for the parts of the dinosaur that make it different from the bird, and then touch those parts of the dinosaur to change them.

#### **Adaptations: Feathers**

The first dinosaurs were covered in scales. Some later developed simple hair-like structures, which evolved into specialized flight feathers in birds.

#### **Adaptation: Long Arms**

The arms of meat-eating dinosaurs were used for grasping prey. Longer arms combined with feathers to become birds' wings.

#### **Adaptation: Stiff, short tail**

Most dinosaurs had long, flexible tails. Birds evolved shorter, stiffer tails that were lighter and more useful in flight.

This exhibit demonstrates to the visitor how certain adaptations were useful for flight in birds yet these adaptations originated in dinosaurs. The exhibit depicts a dinosaur running and the visitor is invited to select certain features of the dinosaur that, over the course of dinosaur and bird evolution, evolved to facilitate flight.

Small anatomical changes that promoted flight include feathers, lengthening of the arms and the development of a stiff, short tail. Dinosaurs possessing these traits had advantages over dinosaurs that did not possess these traits. Feathers, for example, were useful for insulation. Long arms, combined with feathers fostered flying thus improving locomotion and hunting skills. A stiff, short tail also helped provide stability during flight. With possession of these traits, some dinosaurs could survive and were more likely to reproduce. When these dinosaurs reproduced, they produced offspring who inherited these traits, which, themselves, exhibited slight variations in these original traits. Over time, variations accumulated giving rise to flying dinosaurs and ultimately to birds.

## **EXHIBIT 8.**

**Interactive Game: Natural Selection of Medium Ground Finches on Daphne Major allows visitors to measure the beaks of finches that lived on the Galapagos Islands. See why the finches with larger beaks that enabled them to open large tough seeds during hot, dry weather conditions went on to reproduce.**

The Medium Ground Finch *Geospiza fortis* is located on the island Daphne Major, an island in the Galapagos Island chain. Charles Darwin visited this island over 150 years ago. He postulated that changes in the beak sizes of finches reflected the types of seeds that were available; the abundance of certain types of seeds was correlated to weather conditions on the Galapagos. Small, soft seeds were typically associated with wet seasons whereas hard, tough seeds typically occurred during hot, dry seasons.

In this exhibit visitors play the role of scientists traveling to Daphne Major during the wet season, when both small, soft seeds and large, tough seeds are available. Using a caliper, the visitors measure the beaks of finches and find that some finches have larger beaks than others.

Finches with small and large beaks were able to crack open the small, soft seeds to eat, however, large, tough seeds could only be eaten by finches with large beaks. The presence of over 1,000 finches was recorded under these conditions. However, a year later, hot, dry weather conditions prevailed and only large, tough seeds were available. The finch population diminished to less than 200!

It was found that the remaining finches typically had large beaks and were able to use these large beaks to open the large, tough seeds, the only seeds that were available under these weather conditions. The finches with large beaks were able to eat whereas the finches with small beaks, which could not open the large, tough seeds, starved. The finches with the large beaks went on to reproduce. Their offspring, like their parents, typically had large beak sizes.

This is evolution by *natural selection*. Traits that give an advantage to members of a population that enable them to survive and reproduce—passing their traits onto the subsequent generation —can, over many, many generations lead to new kinds of organisms.

## **EXHIBIT 9.**

### **Moa Bird Bone Dig**

The evidence for evolution is in the bones (mirroring the message of the exhibit with the skeletons). Scientists find fossil bones but mostly dig them from rock. In this exhibit visitors can dig like a scientist in order to gather information about evolution.

The Moa is a prehistoric bird from New Zealand, as is the kiwi, and is distantly related to the kiwi and recently became extinct. Moa are members of the order Struthioniformes (or

ratites). The ten species of moa are the only wingless birds, lacking even the vestigial wings that all other ratites have. They were the dominant herbivores in New Zealand forest, shrubland and subalpine ecosystems for thousands of years, and until the arrival of the Maori were hunted only by the Haast's Eagle (the largest known eagle). All species are generally believed to have become extinct by 1500 AD, mainly due to hunting by Māori.

Moa bones (and the bones of other extinct birds) have been found in caves throughout New Zealand. The two main ways that the moa bones were deposited in such sites were: 1. Birds that entered the cave to nest or escape bad weather, and subsequently died in the cave; and 2. Birds that fell into a vertical shaft and were unable to escape

The kiwis were formerly regarded as the closest relatives of the moa, but comparisons of their DNA suggest they are more closely related to the Australian emu and cassowary.

#### **Scientists 'reconstruct' giant extinct moa bird using ancient DNA – article in Khabar Express**

Adelaide, July 3, 2009 “Scientists have performed the first DNA-based reconstruction of the giant extinct moa bird, using prehistoric feathers recovered from caves and rock shelters in New Zealand.

Researchers from the University of Adelaide and Landcare Research in New Zealand have identified four different moa species after retrieving ancient DNA from moa feathers believed to be at least 2500 years old.

The giant birds, measuring up to 2.5 metres and weighing 250 kilograms, were the dominant animals in New Zealand's pre-human environment but were quickly exterminated after the arrival of the Maori around 1280 AD. PhD student Nicolas Rawlence from the University's Australian Centre for Ancient DNA says until now, the scientific community has not known what the 10 different species of moa looked like.

"By using ancient DNA we have been able to connect feathers to four different moa species," he said.

The researchers compared the feathers to others found in the sediments from red-crowned parakeets that are still living today, determining they had not faded or changed in colour.

They then reconstructed the appearance of the stout-legged moa, heavy-footed moa, upland moa and the South Island giant moa.

"The surprising thing is that while many of the species had a similar, relatively plain brown plumage for camouflage, some had white-tipped feathers to create a speckled appearance," said Rawlence.

## **EXHIBIT 10.**

### **Charlie's World Vignette**

Fly through time with Kiwi and Charlie. Find where kiwis are from on the map of New Zealand. See a real, modern-day kiwi (stuffed) and a fossil replica of Archaeopteryx (a prehistoric bird).

### ***Charlie and Kiwi's Evolutionary Adventure STORY THEATER***

In this section, a brief summary describes the information that is provided in the animated story, *Charlie and Kiwi's Evolutionary Adventure*. The information outlines how evolutionary biology is reflected in the story with attention paid to key points of evolutionary processes.

### ***Charlie and Kiwi's Evolutionary Adventure***

**This is a story about a boy named Charlie, who has to write a report about birds...**

**Who knew a school report would turn into a time-traveling adventure?**

**Charlie and Kiwi go back in time, looking for Kiwi's ancestors. With the help of an ancient fossil or two, they discover a surprising secret about Kiwi---and all birds.**

Charlie, the young boy in the story, has to write a report on kiwis. His friends who claim that kiwis are not "cool birds" tease him. Charlie begins his daunting task of writing the report but falls asleep as he thinks about what to write. During his sleep, Charlie dreams that his great-great-great-great Grandpa Charles, a bird expert, appears<sup>1</sup>.

Charlie explains to Grandpa Charles that he must write a report about kiwis. Grandpa Charles points out several avian traits, particularly feathers and wings, to demonstrate that kiwis are birds. Using a time machine, Charlie and Grandpa Charles travel back in time, to the time of dinosaurs. Grandpa Charles displays a fossil of *Archaeopteryx*, the ancestral link between dinosaurs and birds. Grandpa Charles explains to Charlie that some dinosaurs had feathers possibly for keeping them warm. He continues that, in each generation of newly born dinosaurs, some dinosaurs had feathers. Those dinosaurs with feathers kept warm and were able to grow up and reproduce whereas those without feathers died off.

He adds that little changes such as the gradual development of feathers over the course of many generations are continually inherited by offspring. Over time, these traits result in the formation of different groups of organisms which themselves are composed of different kinds or, species.

Charlie and Grandpa Charles travel forward in time and explore the environment in kiwi's native land, New Zealand. Grandpa Charles goes on to explain to Charlie that in New Zealand, flying predators are abundant. Therefore it is more advantageous for birds (such as the kiwi) not to fly. Further, if food can be obtained by foraging on the ground using specialized features employed for this purpose, those birds possessing such structures have an advantage over kiwis lacking these structures. Kiwis with the specialized structures are able to eat and thus survive and reproduce. Modern kiwis have the characteristics that they do because over many generations advantageous traits were repeatedly inherited. These traits have also varied over these many generations such that they have provided most kiwis with a selective advantage over kiwis without these traits. Over time, modern kiwis exhibit adaptations that maximize the suitability and reproductive success for living in their particular habitat.

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<sup>1</sup> For brevity, great-great-great-great Grandpa Charles will be referred to as Grandpa Charles for the remainder of this description.

After exploring the origins of kiwis and the development of their features, Charlie and his Grandpa Charles travel back to their respective times. With the knowledge obtained from Grandpa Charles and through his own observations, Charlie is able to write his report and to demonstrate to his classmates that the kiwi is, in fact, a “cool bird,” the product of millions of years of processes that together encompass evolution.

### ***Charlie and Kiwi’s Evolutionary Adventure: Discovery Box Element Descriptions***

The descriptions below provide information and a reflection of how each discovery box in the exhibition pertains to basic evolutionary mechanisms. The activities in the discovery boxes are designed to illustrate, in a tactile and inter-active manner how the process of evolution occurs. Emphasis is placed on various evolutionary mechanisms primarily as they reflect natural selection.

Visitors play games, work puzzles and participate in hands-on-activities that enhance understanding of evolutionary concepts while providing meaningful, multigenerational, minds-on play. The table with open shelves provides space for each of the discovery boxes and a surface area to display contents of one or two of the discovery boxes at a time. Visitors can use the tables and chairs and stools to look at the materials more closely. There are also books on evolution and birds, dinosaurs and fossils that can be used with the boxes or viewed separately. *However, these materials can be placed in a discovery activity room if you feel you do not have adequate supervision in the exhibition.*

## **DISCOVERY BOXES**

### **BOX 1.**

#### **Who Survives?**

#### **Camouflage/Moth Box**

- 1. Put all the moths on the light tree bark.**
- 2. Pretend you’re a hungry bird hunting for moths.**  
*(Which ones do you find first?)*  
*(Which ones are harder to see?)*
- 3. Next, put all the moths on the dark tree bark.**
- 4. Again, pretend you’re a hungry bird.**  
*(Do you find different moths first?)*  
*What helps a moth to keep from being eaten?)*

Here’s the story line behind the moth game.

In England, before the 1800’s, trees were light-colored.

Then air pollution got so bad it turned the trees dark. Moths that lived on those trees evolved...

Long ago, dark moths were easy for birds to see and catch. Light moths survived to reproduce, so most moths were light-colored.

With pollution, the trees grew dark. Light moths were easier for birds to catch. Dark moths survived to reproduce, so most moths were dark.

With cleaner air and trees, light moths once again had an advantage and became more common.

This natural selection in action.

When the world changes, some animals have features that help them survive---things like color, size, or strength. Their babies can inherit such features.

Over many generations, a useful feature will become more and more common and the population will look different from before.

- Long Ago and Today (clean air)
- Light tree bark
  - ❖ Pretend you're a hungry bird hunting for moths.
  - ❖ *(Which ones do you find first? Which ones are harder to see?)*
- Mid-1800's-1900's (polluted air)
- Dark tree bark
  - ❖ Pretend you're a hungry bird hunting for moths.
  - ❖ *(Which ones do you find first? Which ones are harder to see?)*

Light colored moths were prevalent prior to the Industrial Revolution in Europe during the 1800's. However, throughout the course of the Industrial Revolution, the trees on which light-colored moths rested (that is their environment) changed from a light color to a darker color due to soot released by factories collecting on the surfaces of trees. Within each population of light colored moths, there were some individuals that had varied in their coloration in that they were darker, even while the trees were lightly colored. These darker moths were more easily seen by predators and readily eaten. Few, if any, were able to survive and reproduce and, consequently, their darker colored trait was not inherited by a subsequent generation. Further, those moths that had a lighter color had a selective advantage over the darker moths; light-coloration was an adaptation for surviving and, potentially reproducing, in an environment that promoted light coloration.

Over time, light coloration was inherited by the offspring of those moths who could survive and reproduce. However, the environment changed as soot from factories began darkening the light-colored trees. Those moths that had light-coloration were more readily seen by predators and eaten. Those variants, on the other hand, that had a darker variation in color, were not as easily seen by predators and not eaten. This gave darker colored moths a selective advantage to survive and reproduce. Their offspring would then inherit increasingly darker coloration and, over time, subsequent moth populations would

display darker coloration. As air pollution decreased, less and less soot collected on trees turning the trees lighter in color. The effect of this was that the advantage of the adaptation for having darker coloration lessened because darker colored moths were more easily seen by predators and eaten; the darker colored moths were not able to survive long enough to reproduce while the lighter colored moths were. Over time, the population of lighter colored moths shifted back to increasingly lighter colors thus having lighter coloration provided a selective advantage in this cleaner environment.

## **BOX 2. WHAT AM I?**

**Is this fossil a bird or a dinosaur (It's a copy of a fossil *Archaeopteryx* that lived 150 million years ago.)**

- 1. Use the magnifying lens to look closely at the fossil.**
- 2. Look for ways the animal was like a bird.**  
*(Does it have wings? Feathers? A wishbone? How many toes?)*
- 3. Look for ways the animal was like a dinosaur.**  
*(Does it have teeth? Claws? A bony tail?)*
- 4. Do the *Archaeopteryx* puzzle for clues.**

***Archaeopteryx* linked dinosaurs and birds**

**The first *Archaeopteryx* fossil was unearthed in 1861. A stunning scientific find, it seemed to be part dinosaur and part bird. It's evidence that birds evolved from dinosaurs. Scientists consider *Archaeopteryx* to be one of the first birds.**

***Archaeopteryx* was like a dinosaur. It had:**

- **Teeth**
- **Claws on its arms (wings)**
- **A long, bony tail**

***Archaeopteryx* was like a bird. It had:**

- **Wings**
- **Feathers**
- **A wishbone**
- **Three toes on each foot.**

*Archaeopteryx* represents a transition between birds and reptiles. Birds did not simply “evolve from dinosaurs.” They share what is known in evolutionary biology as a common ancestor. It is from this common ancestor that some reptiles (non-avian theropods) and birds branch apart onto two separate evolutionary lines or lineages. *Archaeopteryx* is dated to be approximately 150 million years old and it is from this line that modern birds arose. It should be noted that there is no one single specimen of *Archaeopteryx* and, indeed, there are three specimens that were found. These specimens represent populations of *Archaeopteryx* and it is within individual members of these populations

that reptilian and avian traits are seen. Dinosaurs, and, indeed all reptiles, exhibit teeth, claws on their arms and a long, bony tail. Birds have wings, feathers, three toes on each foot and a furcula or wishbone. Like reptiles, birds once had teeth but these teeth, over many generations, became reduced and eventually lost. The toes and manus (hand) claws are used by birds and some reptiles for grasping and tree climbing both of which are reptilian and avian behaviors and suggests that *Archaeopteryx* is, indeed, an intermediate form between these two lines. The scales of reptiles are analogous to bird feathers. Further, birds have scales on their feet lending further support that reptiles and birds share a common ancestor: it is clear from the fossil specimens of *Archaeopteryx* that *Archaeopteryx* had feathers. The furcula or wishbone, which helps secure the muscles used in flight to the sternum and coracoid, is found in both theropod dinosaurs and birds. It is from all of these structures that it can be ascertained that birds and theropod dinosaurs arose from a common ancestor.

### **Box 3.**

#### **Busy Beaks**

**How does each bird use its beak?**

- 1. Look at the bird skulls and their beaks.**
- 2. Match a bird picture to each beak.**
- 3. Match an action word to each beak.**
- 4. Check the symbols on the bottom of each to see if all three match up.**

**Why do birds have different kinds of beaks?**

**Each beak is good for eating different foods: one shape is good for cracking seeds, another for tearing meat and yet another for digging up bugs. With their different beaks, birds are *adapted* to catch and eat foods available where they live.**

**The blue jay lives in the forest. It uses its strong beak to crack open seeds and nuts and to catch bugs.**

**The kiwi is a flightless bird from New Zealand. It sniffs out worms, bugs and grubs with its long beak.**

**The harpy eagle flies through South American rainforests, hunting for monkeys, sloths and opossums. It tears into them with its powerful beak.**

**The macaw, a kind of parrot, lives in the rainforest. Its thick, strong beak can crack the hardest nuts.**

**The woodpecker lives in forests with large trees. Using its sharp beak, it digs holes to find bugs under the bark.**

**The spoonbill wades in marshes along our southern coast. It sweeps its wide beak through the water and grabs any fish it feels.**

**The toucan lives in tropical forests in South America. It uses its big beak to pick fruits and eat bugs.**

**Crack = Blue Jay**

**Sniff = Kiwi**

**Tear = Eagle**

**Grip = Macaw**

**Dig = Woodpecker**

**Grab = Spoonbill**

**Pick = Toucan**

Each of the birds depicted in this discovery box exhibits a specific adaptation for feeding. Although all birds share a common ancestor, slight variations in populations of ancestral bird populations enabled certain birds to thrive within a given environment. For example, some members of early bird populations had long, powerful beaks, which allowed them to crack open nuts in environments where hard-shelled nuts were plentiful. Those birds unable to crack these nuts would not be able to eat and would probably die before reproducing. The birds able to crack hard-shelled nuts, on the other hand, would be able to eat, survive and reproduce which, in turn, would allow these birds to pass on their traits to their offspring. If, however, the environment were to change such that hard-shelled nuts were no longer available, the birds that feed on these nuts would die and not be able to reproduce. A long, powerful beak would no longer be an advantage and a different type of beak may be more advantageous. It should be noted that this change in beak structure might occur over many generation thereby requiring a long expanse of time.

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#### **BOX 4.**

##### **Fancy Feet**

- 1. Look carefully at the bird feet (*How many toes? Do all the toes face forward? Is there webbing?*)**
- 2. Match a bird picture to each set of feet.**
- 3. Match a description card to each set of feet.**
- 4. Check the symbols on the bottom to see if all three match up.**

##### **How did bird feet get to be so different?**

**Different bird feet are good for different things, like grabbing or swimming. If one bird's feet are a little different and grab or swim a little better, that bird has a better chance of surviving. (*For example, if a hawk has sharper claws that grab prey a little bit tighter, it will catch more food. It will survive and have babies with sharper claws.*)**

**This bird has three toes pointing forward and one backward. With these feet, it can hold tight onto a perch.**

**This bird has long, thin toes that spread its weight over a large area. It can walk easily on muddy ground near the water's edge.**

**This bird has wide, webbed feet. It swims using its feet like paddles.**

**This bird uses its sharp claws and powerful feet to catch, kill and carry prey.**

**This bird has two toes pointing forward and two backward. With these feet, the bird can climb up, down and sideways on trees.**

The birds shown in this discovery box demonstrate a wide array of bird feet that were derived from the common ancestor of all birds. In the ancestral bird population, there was some variation in the basic foot structure such that some individuals of that population had a selective advantage with regard to surviving in certain types of environments. Those birds with feet that enabled them to survive under certain environmental conditions were able to reproduce and pass on their characteristic foot traits to their offspring. For example, webbed-feet are an adaptation for aquatic environments and birds that have this adaptation today thrive in aquatic areas. Upon reproducing, the trait of having webbed-feet is passed onto their young. Birds of prey such as the harpy eagle are able to tear meat with their sharp claws. Assuming that the environment does not change, the trait for sharp claws is passed onto their young. These young, in turn, will give rise to future generations of sharp-clawed harpy eagles.

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#### **BOX 5.**

##### **Are You My Baby?**

- 1. Look at the mother and father cat.**
- 2. Decide which of the other animals could be their children. (*Do they look alike? Are they the same kinds of animals?*)**
- 3. Check your answers on the back of the pictures.**

**Children are like their parents...sort of**

**Cats, and all living things, inherit features from their parents. Babies will always be the same kind of animal as their parents. But they won't always look the same. Some features (like color or size) might be very different.**

**White Cat**

**Yes, this cat could be their baby. It has the same coloring as the mother.**

**Grey Cat**

**Yes, this cat could be their baby. It has the same coloring as the father.**

**Mottled Cat**

**Yes, this cat could be their baby. It doesn't look like either parent---but it might look like the grandparents!**

**Striped Cat**

**Yes, this cat could be their baby. It doesn't look like either parent---but it might look like the grandparents!**

**Tiger**

**No, this cat could not be their baby. A tiger is a different kind of cat. (It's a different species!)**

**Saber-toothed tiger**

**No, this cat could not be their baby. A saber-toothed tiger is a different kind of cat. (This species died out 10,000 years ago.)**

**Turtle**

**No, a turtle could not be their baby. It's a different kind of animal.**

All living things inherit their characteristics from their parents. Nevertheless, there is still some variation in these characteristics, which makes every individual unique. Members of the same species are able to reproduce and produce viable offspring that, when they reproduce, will pass certain traits onto the next generation. Sometimes, traits can skip a generation but, ultimately, the traits of a given organism can be traced back to an ancestor. In this case, all of the cats shown have characteristics that make them cats; turtles have different traits altogether which is why a turtle could not possibly have come from a cat! Long ago, there was an ancestral population from which all cats arose but, over time, some of the traits changed such that populations of cats began to have traits that were so different from the original ancestral population that they could not reproduce and produce viable offspring with cats from later generations. A new species of cats had evolved. Today, we see many species of cats, from tigers to house cats. Each of these species can breed within the same species but not with other species. Traits within the same species get passed down generation by generation but sometimes, changes may be so great, that a new species develops. Humans have altered the natural selection of cats by artificially selecting traits that we value. None of the breeds of cats (or dogs, for that matter) occur naturally even though the traits we select for artificially do exist in natural ancestral cat and dog populations. Charles Darwin based his idea of natural selection partially on his familiarity with the work of artificial breeding of pigeons.

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**BOX 6.**

**Bird Key**

**A "key" is a step-by-step process scientists use to identify objects. Follow the steps to identify each mystery bird.**

- 1. Pick a bird.**
- 2. Answer the first question. That will put you on the right path and lead to the next question.**
- 3. Answer each question until you get to the end of the path.**
- 4. Check under the flip card. *Did you identify the mystery bird?***
- 5. Pick another bird and do it again!**

**Can this bird fly?**

**Yes** (*toucan, flamingo, cardinal, duck*)

**No** (*penguin, ostrich, kiwi, cassowary*)

**Flightless**

**Does it have a long neck?**

**Yes** (*ostrich, cassowary*)

**No** (*kiwi, penguin*)

**Long Neck**

**Does it have a crest on its head?**

**Yes** (*answer under flip*) *Cassowary*

**No** (*answer under flip*) *Ostrich*

**Short Neck**

**Does it swim?**

**Yes** (*answer under flip*) *Emperor penguin*

**No** (*answer under flip*) *Brown kiwi*

**Flying**

**Does it have a big, long beak?**

**Yes** (*toucan, flamingo*)

**No** (*cardinal, duck*)

**Long Beak**

**Does it have long legs?**

**Yes** (*answer under flip*) *Chilean flamingo*

**No** (*answer under flip*) *Toco toucan*

**Short Beak**

**Does it have webbed feet?**

**Yes** (*answer under flip*) *Mallard Duck*

**No** (*answer under flip*) *Northern cardinal*

All birds are descended from a common ancestor. Over time, variations in the ancestral population were propagated as new generations of birds developed. The individuals of each population inherited characteristics from their parents, which were amplified as further generations developed. Some of these variations provided a selective advantage to the birds that had these variations (otherwise called adaptations) within a given environment. These traits would select for certain individuals to survive, making them more likely to reproduce. The result is a tremendous diversity amongst birds that make them distinguishable from other birds. The differences in birds can be used to identify them making the key above a useful instrument for identification.

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## **Box 7.**

### **Family Features**

- 1. Look at the pictures on the cards.**
- 2. Use the mirror to see if you have that feature.**
- 3. Compare yourself to others in your family.**

### **All these features are inherited**

**People inherit these features from their parents---but sometimes the features are hidden.**

**If you have one of these features but other family members don't (or the other way around), the feature may show up again in your children or grandchildren.**

### **Widow's Peak**

**Does your hair come to a point in the middle of your forehead?**

**Does anyone else in your family have a widow's peak?**

### **Freckles**

**Do you have freckles?**

**Does everyone else in your family have freckles?**

### **Earlobes**

**Does your earlobe hang free like in the top photo?**

### **Dimples**

**Dimples are dents that show up when you smile. Not sure if you have them? Smile and see!**

**Do your grandparents have dimples?**

### **Cleft chin**

**A cleft chin is caused by a groove in the bone underneath.**

**Is there anyone in your family with a cleft chin?**

### **Smelling Freesia**

**Can you smell this flower's scent? Most people can but a few can't.**

**Let others try.**

We inherit the features that make us who we are from our parents. Some of these features, however, do not always get passed down to us but other traits do. Often times, we may inherit traits from our grandparents even though our parents may not have these traits! This is variation or slight changes that make us individuals while still keeping those characteristics that makes us human. Over time and due to the introduction of new traits, humans (and, indeed, all living things) change. Those who have features that

enable them to survive under a given set of environmental conditions may reproduce, passing on their traits further.

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### BOX 8.

#### We Can Fly!

**Birds and bats both fly, but the bones in their wings are different.**

1. Try on a set of wings.
2. Look at the hand bones (blue) and the fingers (red).
3. Compare the bird and bat wings. (*How many fingers does the bat have? What about the bird?*)

#### Why do birds AND bats fly?

Flying is great---it helps animals to:

- Find and catch food
- Escape enemies
- Travel fast and far

**These advantages drove the evolution of wings in birds---but they're not the only animals that fly. Bats are flying mammals. The differences between bird and bat wing bones show that these fliers have different ancestors and evolved flight differently.**

#### Where did wings come from?

**Some animals evolved wing-like arms that could do things like catch food. Later, the arms became useful for flight. Animals that could fly did better than those that couldn't. They survived and passed the ability to fly on to their offspring.**

Birds and bats both fly but do NOT come from a common ancestor. Upon examination of the wings of each of these animals, it can be seen that bird wings are mostly supported by the skeletal structures known as the radius, ulna and wrist bones with the one of the digits projecting outward and two of them being fused (see Fig. 1A). Bat wings are altogether different in structure with the digits extending outward from the ulna and radius very similar to that of the digits in the human hand (see Fig1B).

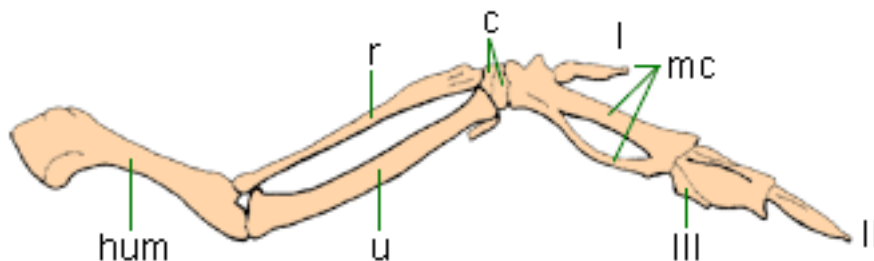


Fig 1A. A generalized bird wing (hum= humerus, r= radius, u= ulna, c= carpus, mc= metacarpus, I-III= numbered digits). Adapted from Padian 1985 and University of California Museum of Paleontology website.

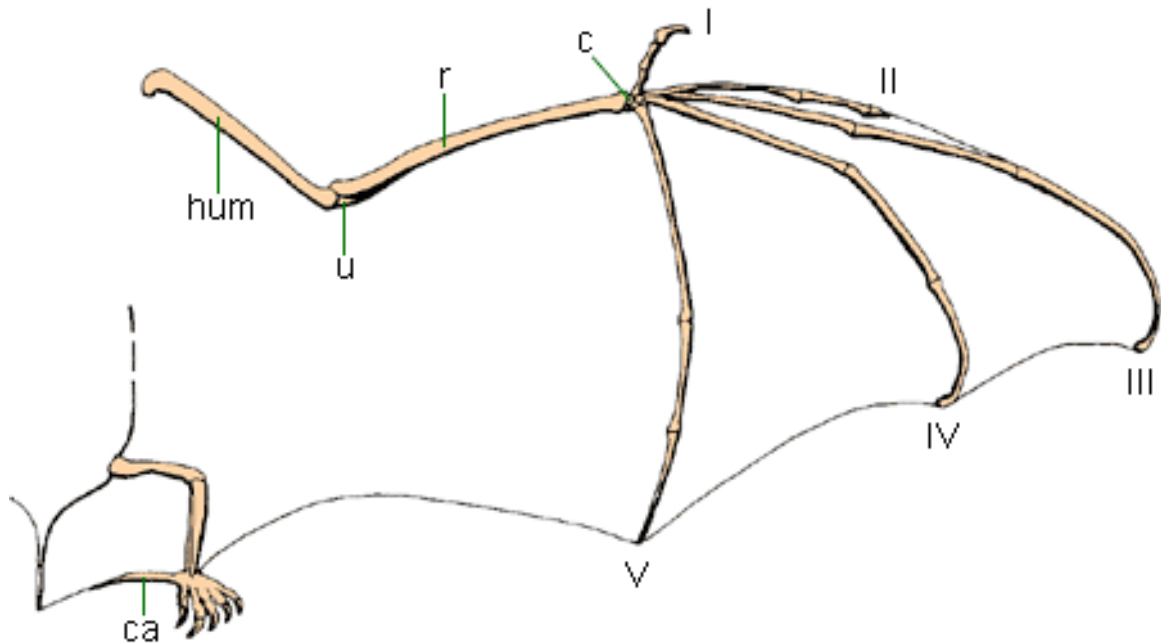


Fig 1B. A generalized bat wing (hum= humerus, u= ulna, r= radius, c= carpus, ca= calcar, I-V= numbered digits). Adapted from Padian 1985 and University of California Museum of Paleontology website.

The differences between these wing structures can only be accounted for in studying the fossil record. Similarities in the limb and wing structures of meat-eating dinosaurs and early birds, respectively show many similarities. Limb structures in bats and some early mammals demonstrate similarities as well. In interpreting the fossil records of birds and bats, their occurrences in time also provide a clue: the common ancestor between birds and dinosaurs occurred millions of years earlier than the common ancestor between bats and other mammals. In other words, bird flight began much earlier than bat flight, which lends further credence to the fact that bird flight and bat flight are not linked. Regardless of when in the past flight evolved in these two lineages, the same basic evolutionary mechanisms were at work: Individuals within a population had a selective advantage in having structures that could help them fly. Over time and many generations, the structures employed in flight were passed onto the offspring of those individuals that had these structures. In other words, these features were inherited and, because they were useful, these features gave an advantage to those individuals that had them, which allowed them to more readily survive and reproduce.

## **BOX 9.**

### **Nature's Variety**

**These skulls come from turkeys of all the same age and kind. But each one's a little different.**

**See if you can find the widest skull.**

- 1. The skulls are delicate, so PLEASE BE GENTLE!**
- 2. Use the calipers to measure between the red dots.**
- 3. Measure all the skulls and compare.**  
*(Which turkey skull is widest? Which is narrowest?)*
- 4. Think about the living turkeys and how they were different.**  
*(Which turkey would have been more likely to survive if hard acorns were the only food around?)*

**Those little differences make a difference**

**Turkeys, like all animals are always a little different from each other. Those little differences can help the animal have a better chance of survival.**

**A turkey born with a wider, stronger skull and beak will be better at cracking large, hard acorns. When small seeds and fruits are scarce, that turkey can survive by eating large acorns.**

**Answer: Turkeys with wider skulls can bite harder. When food is scarce and only hard seeds (like acorns) are left, they're more likely to survive and have babies.**

**Some of their babies will have wider skulls and so will *their* babies. Over a long time and many generations, turkeys will have wider skulls than their great-great-great-grandparents.**

All living things inherit traits from their ancestors (parents, grandparents, great grandparents, etc.) However, in each generation, individual offspring will have slight variations in their phenotype and genotype that make them distinct from all of their family members. Some of these traits may provide an advantage to certain individuals who possess them. For example, certain traits may enable certain individuals to better cope with environmental conditions or the traits may provide an advantage in attracting a mate. The above activity describes how some turkeys have wider, stronger skulls than some of their relatives. The turkeys with wider, stronger skulls and beaks have an advantage over their family members with narrow, weaker skulls and beaks in that the turkeys with the wider, stronger skulls and beaks can obtain food more readily by cracking open acorns. Consequently, turkeys with wider, stronger skulls and beaks may be more likely to survive and reproduce thereby possibly passing this trait on to their offspring. This second generation of offspring may reproduce and pass these traits onto

their offspring. Through time, certain characteristics may make future generations of turkeys markedly distinct from their ancestors.

**BOX 10.**

**Little Differences Make a Difference**

**Use the measuring tape---and your eyes---to find all the differences between these two baby bluebirds.**

**Check the answer key to see if you found them all.**

**Answer Key**

<b>Feature</b>	<b>Bird 1</b>	<b>Bird 2</b>
<b>Legs</b>	<b>Long</b>	<b>Short</b>
<b>Tail</b>	<b>Short</b>	<b>Long</b>
<b>Wings</b>	<b>Long</b>	<b>Short</b>
<b>Beak</b>	<b>Short</b>	<b>Long</b>
<b>Eyes</b>	<b>Red</b>	<b>Brown</b>

**Parents have babies that are like themselves (and different from other kind of animals). But babies are not *exactly* like their parents or each other.**

**Little differences in size, color and other features can make an animal better---or worse---at finding food, getting away from predators, or finding mate.**

**To think about...**

**Which features might make one baby bluebird better than another at getting food?**

**Answer:**

*It depends on the kind of food*

*The birds can find in their environment.*

*A long beak is good for reaching hidden insects.*

*A short beak is better for cracking hard nuts.*

Although siblings may share the same parents, there are slight characteristic differences that make each sibling unique from both its parents and its other siblings. Some of these characteristics may enable certain individuals, even within a family, to survive within a given set of environmental conditions such that the individuals' chances of reproducing are increased. Those individuals who reproduce pass their traits onto their offspring who will, in turn, pass traits onto *their* offspring. Many factors affect whether or not an animal will reproduce but those best suited to their environment are more likely to reproduce thereby passing on their traits to future generations.

## **BOX 11.**

### **Pieces of the Past**

**Put the puzzle pieces together to show how Birdie inherited its wing shape.**

*(Which model bird has the same shape wing as Birdie?)*

**Animals inherit all their features, such as shape, size and color, from their parents. Sometimes these features skip a generation, or only occur once in each generation.**

Animals inherit traits not only from their parents but from their grandparents as well. With each successive generation, there are variations that make individuals who they are. Some individuals may inherit traits that their parents did not inherit but, somewhere in the family history of the individual, the traits were at one time present.

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## **BOX 12.**

### **The Right Stuff**

**Roll the dice to see what features from your baby bird will inherit from its mother and father.**

**Use those features for your baby bird.**

**To think about...**

**Does your baby bird look exactly like one of the model birds?**

**If not, could it be from the same family?**

**Every baby inherits a unique combination of features from its parents. *(Do you and your birth parents have the same eyes? Nose? Hair color?)***

**It's the same for animals like birds!**

**In each new generation, a few bay birds inherit the right combination of features to find food and survive.**

**When those birds grow up and mate, they pass on the features that helped them succeed to some of their own babies.**

When animals mate, the traits of the parents stand a chance of being passed onto their offspring. Some traits are more likely to be passed on than others. These are known as dominant and recessive traits, respectively. Along with inheriting certain traits from their parents, each individual offspring will vary in some way making it unique from the rest of its family. Further, some traits may provide an advantage to individuals with those traits making them more likely to succeed in reproducing. These more advantageous traits will be passed onto future generations as a result.

## Glossary

Adaptation = a characteristic that increases the ability of an organism to survive and reproduce particularly with respect to the environment in which the organism is found.

Artificial selection = the non-random breeding of organisms to select for specific traits such that the offspring of the bred organism inherits these traits.

Avian = having to do with birds.

Bipedal = the ability to walk on two legs.

Bird = an air-breathing animal possessing feathers, wings, a backbone, walks on two legs and is warm-blooded. The females give birth to young by laying eggs.

Carnivore = a meat-eating animal.

Common ancestor = an organism in the past from which separate organisms arose. The term suggests a close evolutionary relationship relative to geologic time.

Convergent evolution = the condition in which different organisms have the similar characteristics but have been acquired independent of an evolutionary line.

Coracoid = in birds, these are the bones located to the sides of the sternum towards the wings.

Dinosaur = reptiles, mostly terrestrial, that lived during the Mesozoic Era. Dinosaurs are categorized as such according to the structure of the hip and skull. There are two main orders of dinosaurs, the saurischia (lizard-hipped) and ornithischia (bird-hipped) as illustrated in figures 2A and 2B. The saurischian hip structure exhibits the pubis extending forward with the ischium pointing backward and down. In the ornithischian hip condition, the pubis and ischium together extend backward and down. It was once thought that the ornithischian condition was that found in modern birds as modern birds display the same type of hip structure. However, under further analyses of other traits, it is agreed upon by scientists that modern birds actually share common ancestry with saurischian dinosaurs and that the hip structure found in modern birds developed independently (see convergent evolution) of ornithischian dinosaurs perhaps as adaptations for herbivorous, omnivorous or arboreal behaviors. Further, the skull of dinosaurs has two temporal openings, as do most reptiles indicating that dinosaurs share common ancestry with most other reptiles. Some reptiles are anapsids and, by contrast, lack a temporal opening as is seen in turtles (Fig. 2C). Other reptiles have two temporal openings, however, the bones comprising the cranium are arranged in positions unlike that of diapsids. These are called the synapsids (fig. 3C) and euryapsids (fig. 3D) and are exemplified by pelycosaurs and ancient marine reptiles, respectively.

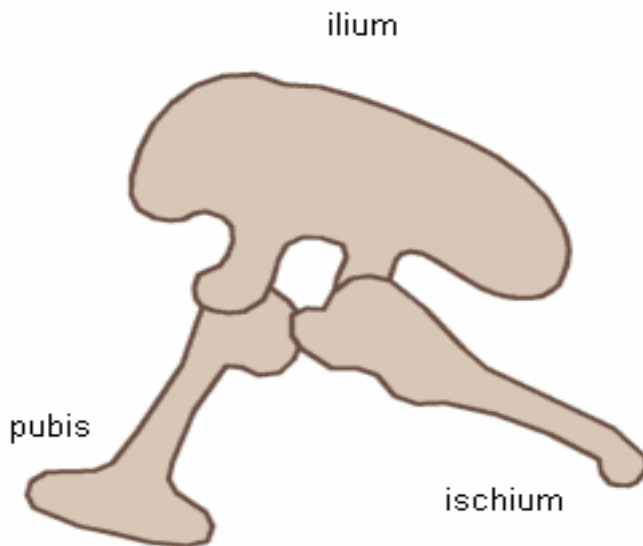


Fig 2A. Structure in the hip of a saurischian dinosaur. Note that the ischium extends backwards whereas the pubis extends forward. Adapted from Wikipedia.com dinosaur page.

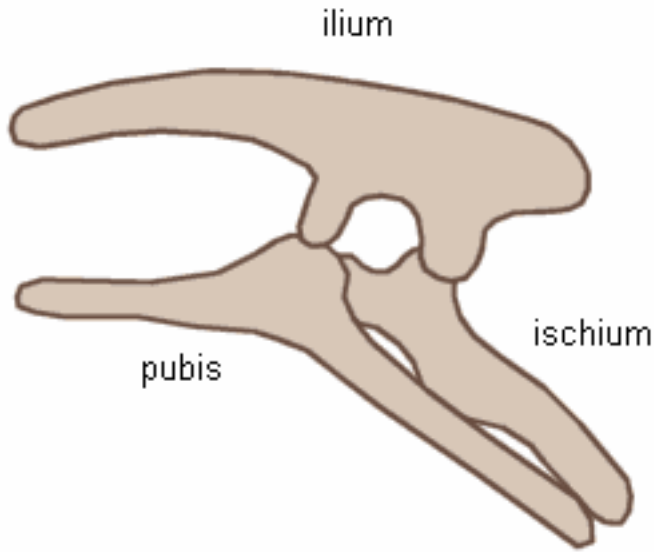


Fig. 2B. Structure in the hip of an ornithischian dinosaur. Note that both the pubis and the ischium extend backward and down. Adapted from Wikipedia.com dinosaur page.

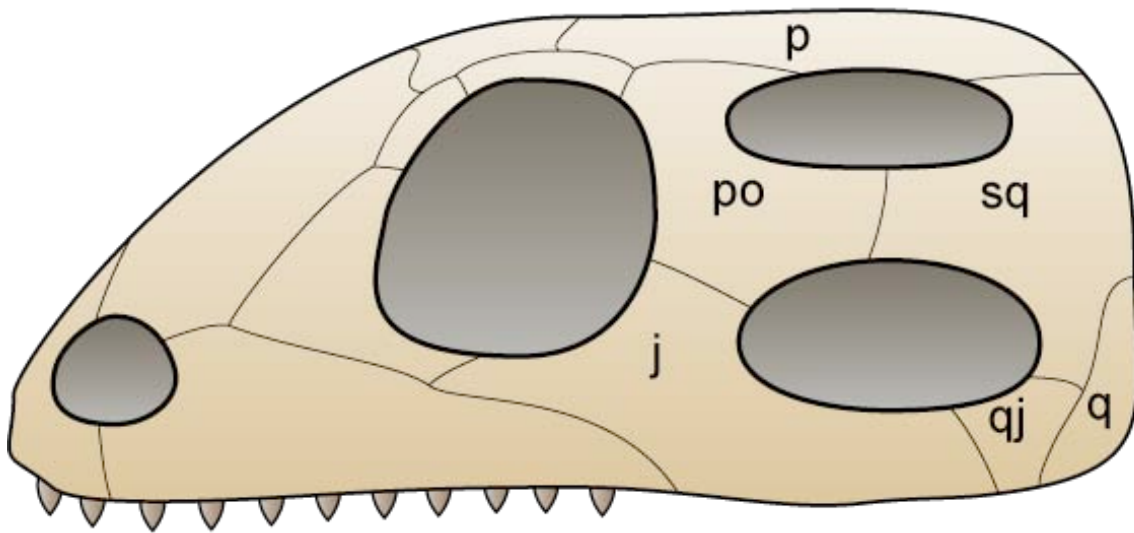


Fig. 3A. The diapsid skull demonstrating two temporal openings as seen in dinosaurs and most other reptiles. Adapted from Wikipedia.com website on diapsids.

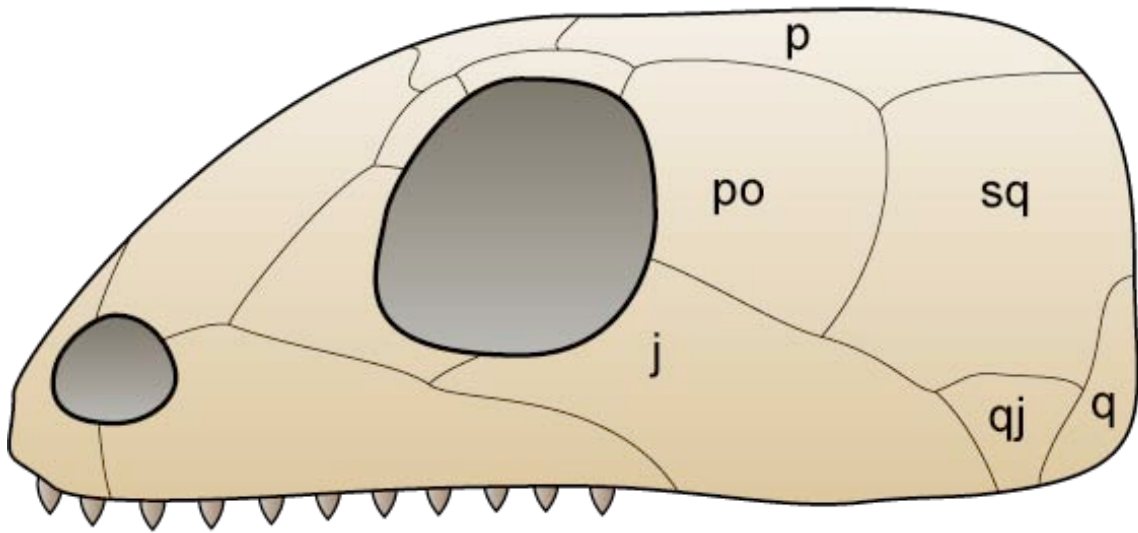


Fig. 3B. The anapsid skull demonstrating a lack of temporal openings. This condition is seen in turtles. Adapted from Wikipedia.com website on diapsids.

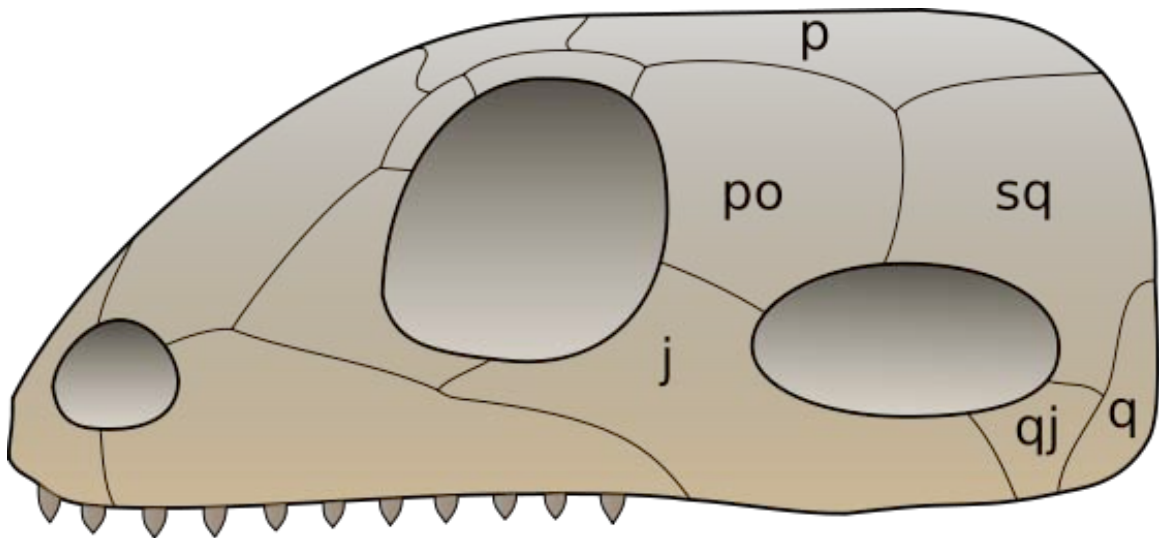


Fig. 3C. Synapsid skull with only one temporal opening as exhibited pelycosaurs. Adapted from Wikipedia.com website on synapsids.

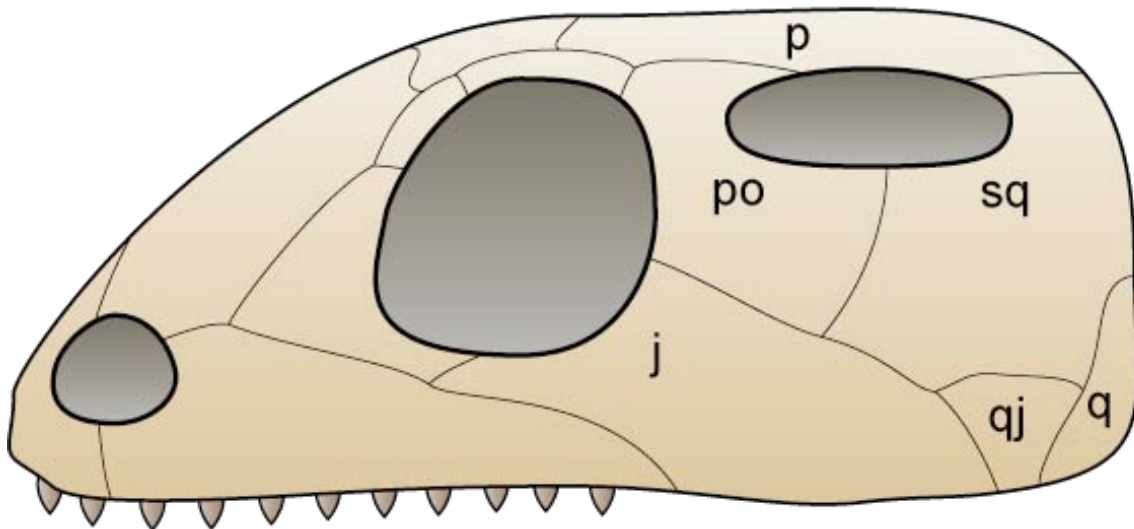


Fig. 3D. Euryapsid skull with only one temporal opening. This condition is seen in the ancient marine reptiles known as ichthyosaurs and plesiosaurs. Adapted from Wikipedia.com website on euryapsids.

Evolution = descent with modification as seen in living things. The process involves variation, inheritance of characteristics from ancestors, selection, time an adaptation or a combination of all.

Fitness = the ability of an organism to pass its genes onto the next generation of offspring.

Furcula = commonly called the wishbone, it is the bone in birds that secures other bones found in the chest that are employed in flight.

Genotype = traits pertaining to an organism's genetic make up.

Genetic drift = reproductive success that is influenced by randomly occurring events in an organism's environment.

Habitat = a location where an organism lives.

Herbivore = a plant-eating animal.

Homologous = characteristics found in organisms that are similar in form and can be traced to an evolutionary common ancestor.

Inheritance = features that an organism receives from its parents.

Natural Selection = non-random reproductive success that occurs such that organisms with characteristics that the number of less fit individuals within a population decreases.

Niche = a location or resource occupied by an organism within its environment.

Omnivore = an animal that eats both meat and plants.

Ontogeny = the life history of an individual organism.

Organism = any living thing.

Phenotype = traits pertaining to the outward, physical appearance of an organism.

Phylogeny = the evolutionary history of a species.

Population = a group of one species living in a given habitat.

Quadrupedal = the ability to walk on four legs.

Radius = a long bone found along the top length of the forearm.

Reptiles = an air-breathing animal that possesses scales on its body, a backbone and is cold-blooded. Females give birth to young by laying eggs.

Selection = the non-random reproductive success of an organism.

Selective advantage = a characteristic that makes an organism more reproductively successful than those lacking the characteristic.

Sexual selection = the non-random breeding of organisms due to the selection of mates with traits that are deemed favorable or attractive.

Species = an organism that can reproduce with others of its kind and produce offspring who, themselves, can reproduce.

Sternum = commonly called the breastbone and located in the center of the chest, this bone helps birds secure muscles used flight.

Thermoregulation = processes relating to the maintenance of body temperature.

Theropod dinosaur = meat-eating saurischian dinosaurs.

Trait = a characteristic or feature of an organism. These can either be physical features or genetic. See phenotype and genotype.

Transitional fossil = the remains of an organism that demonstrates characteristics that are found in two or more organisms thus suggesting common ancestry between those organisms.

Ulna = a long bone found along the central length of the forearm.

Variation = features that make an organism slightly different from others of its kind.

### **Geologic Time Scale**

(mya = million years ago)

Courtesy of The University of Berkeley's Museum of Paleontology Website

#### Phanerozoic Eon

(543 mya to present) Cenozoic Era

(65 mya to today) Quaternary (1.8 mya to today)

Holocene (10,000 years to today)

Pleistocene (1.8 mya to 10,000 yrs)

Tertiary (65 to 1.8 mya)

Pliocene (5.3 to 1.8 mya)

Miocene (23.8 to 5.3 mya)

Oligocene (33.7 to 23.8 mya)

Eocene (54.8 to 33.7 mya)

Paleocene (65 to 54.8 mya)

#### Mesozoic Era

(248 to 65 mya) Cretaceous (144 to 65 mya)

Jurassic (206 to 144 mya)

Triassic (248 to 206 mya)

Paleozoic Era  
(543 to 248 mya) Permian (290 to 248 mya)  
Carboniferous (354 to 290 mya)  
    Pennsylvanian (323 to 290 mya)  
    Mississippian (354 to 323 mya)  
Devonian (417 to 354 mya)  
Silurian (443 to 417 mya)  
Ordovician (490 to 443 mya)  
Cambrian (543 to 490 mya)  
    Tommotian (530 to 527 mya)  
Precambrian Time  
(4,500 to 543 mya) Proterozoic Era  
(2500 to 543 mya) Neoproterozoic (900 to 543 mya)  
    Vendian (650 to 543 mya)  
Mesoproterozoic (1600 to 900 mya)  
Paleoproterozoic (2500 to 1600 mya)  
Archaean  
(3800 to 2500 mya)  
Hadean  
(4500 to 3800 mya)

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## **Websites**

*Understanding Evolution* on University of California Berkeley's Museum of Paleontology website: <http://evolution.berkeley.edu>