I. Exhibit overview and rationale

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 displayed in the exhibition, the Story Theater presented in the exhibition 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. At the end of this guide is a list of references to the Museum of paleontology pages on specific topics of evolution related to this exhibition.

Learning goals

Not everyone who experiences the exhibit will learn the same things from it. Here is a summary of the key evolutionary concepts that we hope visitors of different ages can learn through their experiences with this exhibit.

5- to 7-year olds and up:
• The natural world is diverse; there are many different species.
• Individual organisms of the same species vary from one to the next.
• This variation can be adaptive in particular environments and improve the organism’s chances of survival.
• Different species of organisms are adapted to different environments.
• Parents and offspring look alike.
• Dinosaurs and birds are related.
• Dinosaurs and birds share common features.

8- to 9-year olds and up:
• If the environment changes (e.g., different source of food; temperature change) only those organisms that possess features that are adaptive in the changed environment will survive.
• The surviving organisms will pass those features to their offspring.
• Those offspring will vary—not all of them will possess those adaptive features.
• Dinosaurs lived a long time ago.

10- to 12-year olds and up:
• Those animals with features that increase their chances of survival in a particular environment are more likely to pass these features onto their offspring.
• Over many generations, this will lead to changes in the population.
• Birds evolved from dinosaurs.
• Features shared between birds and dinosaurs are evidence of their common ancestry.
• Dinosaurs lived millions of years ago.
Exhibit overview: 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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Edited by Marcia Rudy

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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.

EXHIBIT 1.
Intro panel

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.
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 descendents form distinct groups. The retention of homologous structures in descendents 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.

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.

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.

**EXHIBIT 3.**

*Why is a kiwi like a kiwi? Or How Evolution Works*
Did birds really come from BIG dinosaurs like this?
OR
Did birds really come from BIG four-legged dinosaurs?
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.

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 descendents who later exhibit traits that we now recognize as truly avian.

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, begin to mate and spread their genes throughout a population, 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 a new form is reproductively isolated from its ancestral form, we have the emergence of a new species. THIS is evolution!

**EXHIBIT 4.**

**Flap 1**
No! Only the small, meat-eating dinosaurs gave rise to birds. (The really BIG dinosaurs all died out.)

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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.)

- **These three share similar bones**
  - Meat-eating dinosaurs
  - Early birds
  - Modern birds

  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.

**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.

**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.
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.

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-curve 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.

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.

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 Akohekhe 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 hark.

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.

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

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.

**EXHIBIT 7.**

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

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.

**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.
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 or 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 (Skeleton above).

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 (claimed to be the largest eagle). All species are generally believed to have become extinct by 1500 AD, mainly due to hunting by Maori.

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) ad a fossil replica of Archaeopteryx (a prehistoric bird).
Charlie and Kiwi’s Evolutionary Adventure

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-great Grandpa Charles, a bird expert, appears.

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.

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

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.