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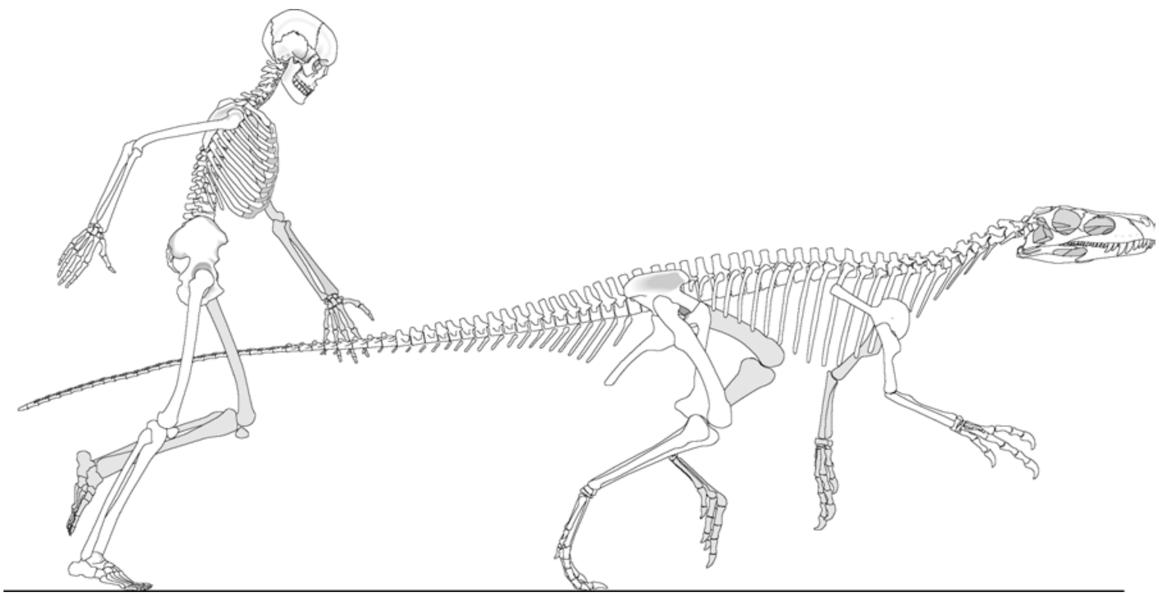
Chapter 9

Living Dinosaurs?



Now, let us be quick to clarify our query. We're not talking about dinosaurs still living hidden in the black waters of Loch Nesse or the darkest jungles of Africa. All but a few crackpots admit that sauropods and plesiosaurs are really extinct. But what about dinosaurs living in your own back yard? It seemed ridiculous. Or so we thought as we packed up our books and moved to Berkeley.

When we arrived we were met by the prospect of living dinosaurs, and it seemed surprising to be confronted with the argument by members of our own department, instead of the street-life of Telegraph Avenue. *Tyrannosaurus* and *Triceratops* obviously did disappear at the end of the Cretaceous, our new colleagues conceded. Nonetheless, one lineage that descended from the ancestral dinosaur survived the impact and eruptions at the K-T boundary. Today, that lineage is represented by over 9,000 species of birds. Furthermore, if birds are living descendants of dinosaurs, isn't it incorrect to say that dinosaurs are extinct?

What does it mean to say birds are dinosaurs? Proponents argued that newly discovered fossils demonstrated that dinosaurs were the ancestors of birds. In addition, new methods for reconstructing evolutionary history and establishing evolutionary relationships were being developed. Applying these methods to the fossil record resurrected dinosaurs from extinction and in effect changed the course of the history of life.

Others at Berkeley argued that the issue was trivially semantic and of no scientific significance. Even if birds did evolve from dinosaurs, they are totally different from the extinct Mesozoic monsters. With the evolution of flight and warm-bloodedness birds entered a new adaptive zone, hence their placement in a separate Class of vertebrates--Aves. Any genealogical connection was dwarfed by the shift to a new adaptational way of life.

If science were democratic the notion of living dinosaurs would have quickly gone extinct. The new methods that produced this perspective were attacked by some of the world's most influential evolutionary biologists. They argued that the procedures were flawed and that they produce flawed results. Moreover, most scientists believed that reconstructing ancient genealogies was virtually impossible to do with any accuracy. Scientists should stick to biological issues that could be observed directly in the modern world. Most scientists adamantly maintained that dinosaurs are extinct.

But scientific arguments are decided on the weight of the evidence rather than the weight of opinion or appeal to authority. With new fossil discoveries, the evidence for a connection between birds and dinosaurs grew steadily in the shadow of the more public brawl over extraterrestrial events and the extinctions at the K-T boundary. What is this evidence, and how do paleontologists view it today?

John Ostrom and Deinonychus

This debate grew from seeds planted many years before our arrival at Berkeley, by Yale University's celebrated paleontologist John Ostrom (figure 9.2).

Figure 9.2. Dr. John Ostrom and *Deinonychus*. (Photo courtesy of Academy of Natural Sciences)

His 1964 discovery of the bird-like dinosaur *Deinonychus antirrhopus* (figure 9. 3) was already a famous story. By our arrival, the discovery's significance had grown far beyond Ostrom's expectations when he first gazed upon the bones in the ground southeast of Bridger, Montana. As he studied them over the next two decades, he became increasingly convinced that the bones might solve one of the oldest and most vexing problems of evolutionary history--the origin of birds.

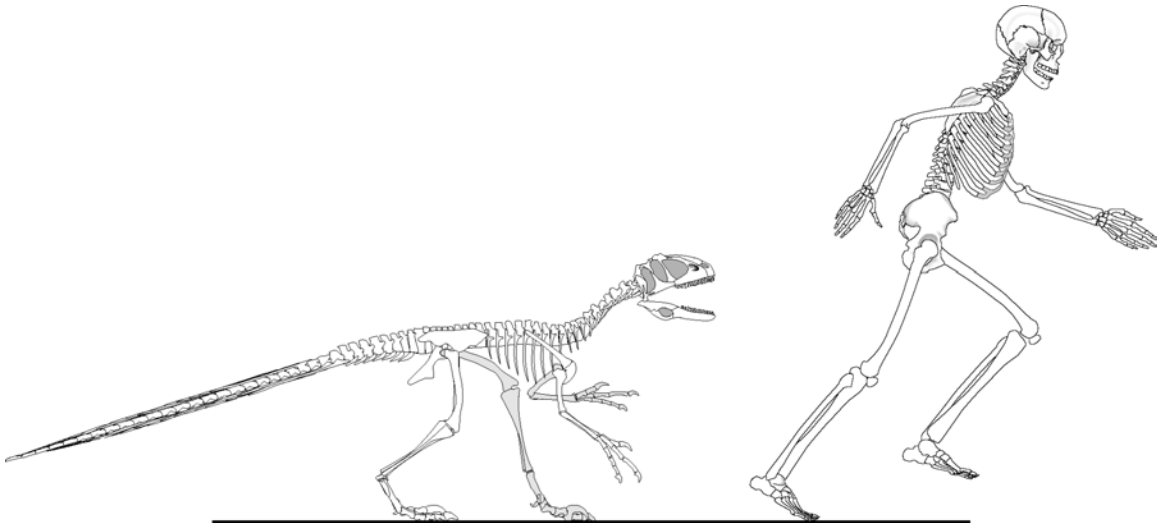


Figure 9.3. The 100-million year old *Deinonychus*, compared to modern *Homo Sapiens*, for scale. Could this dinosaur be a connection between birds and dinosaurs?

Deinonychus was both one of Ostrom's best discoveries and one of his best rediscoveries[1]. Actually, the first bones of *Deinonychus* were collected in 1931 and 1932 by Barnum Brown, the legendary dinosaur hunter from the American Museum of Natural History. The bones came from a ranch on the Crow Indian Reservation, about 35 miles northeast of Ostrom's Yale locality. During the 1931 season, Brown discovered a poorly preserved skull and several dozen additional fragments, including partial hands and feet. Brown knew that small carnivorous dinosaurs are rare and that he had discovered something new and important. Back in New York, he had illustrations prepared, developed plans to mount a skeleton for display, and even came up with a new name for his find --"Daptosaurus." But Brown never finished the manuscript, so the name and illustrations were never published, and the bones never went on display. Thirty-two years after it was made, the first discovery of *Deinonychus* died with Barnum Brown.

Shortly before Barnum Brown's death in 1963, he spoke to John Ostrom, who at the time was a graduate student at Columbia University looking for a dissertation topic in the American Museum's vast fossil collections. Ostrom met Brown to discuss potential topics, including the geology and paleontology of the beds that Brown had prospected thirty years earlier. Ostrom did not choose this as a dissertation topic, but shortly after completing his Ph.D. he picked up the lead again and led a party from Yale to Montana to rediscover *Deinonychus*. His crew found an entirely new site, the Yale *Deinonychus* Quarry. The fossils were hard, black, shiny, and beautifully preserved. The isolated bones of at least three individuals were discovered at this site[1]. A complete hand and foot were collected, as well as those of the skull, so that the whole skeleton could be pieced together (fig. 9.4).

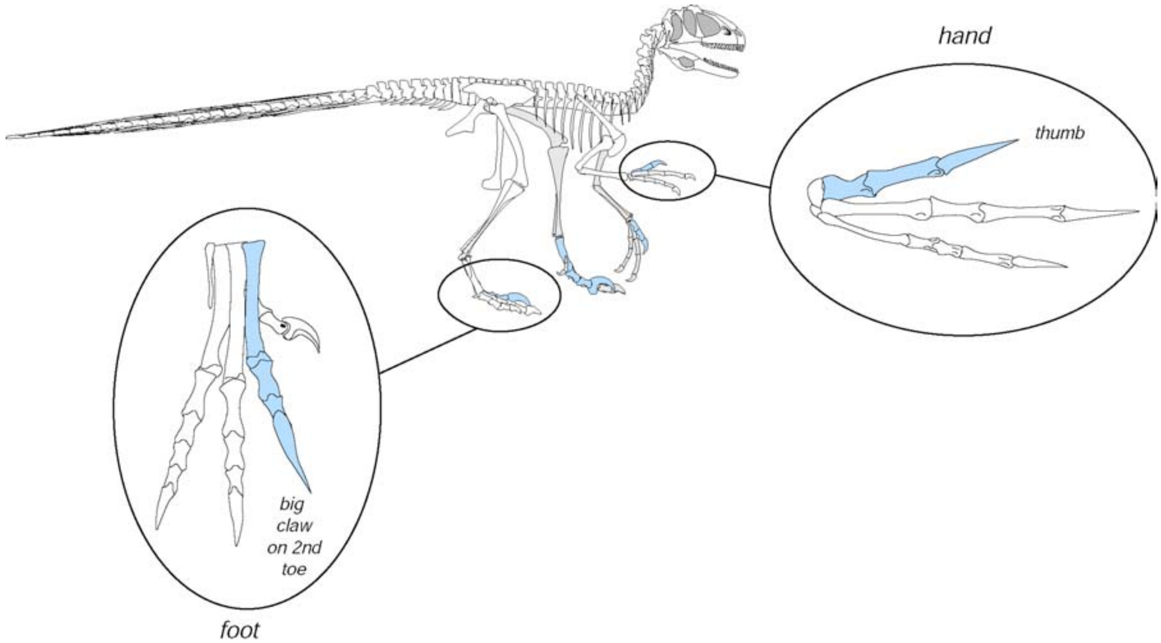


Figure 9.4. A complete hand and foot of *Deinonychus* were recovered from the Yale *Deinonychus* quarry. Eventually, enough bones were recovered that the entire skeleton could be pieced back together. *Deinonychus* stands about 1 meter tall.

Ostrom's rediscovery of *Deinonychus* proved far more significant than Brown's, because with a more complete skeleton, Ostrom was able to study *Deinonychus* in much more detail. It had teeth like steak-knives, whose pointed tips curved backwards and had sharp, serrated edges for sawing flesh (fig. 9.5). It also had long, recurved claws on its hands and feet. *Deinonychus* was predaceous, like its cousin *Tyrannosaurus rex*. But it was much smaller, weighing in at roughly 50 to 100 kilos. The hands on its long, slender arms made a peculiar swivel motion at the wrist. It ran at fairly high speeds. Ostrom recognized *Deinonychus* as "an animal so unusual in its adaptations that it will undoubtedly be a subject of great interest and debate for many years among students of organic evolution"[1]. He was right. *Deinonychus* focused the problem of avian ancestry squarely on dinosaurs, and in the 1970's this was a wrenching shift in perspective.

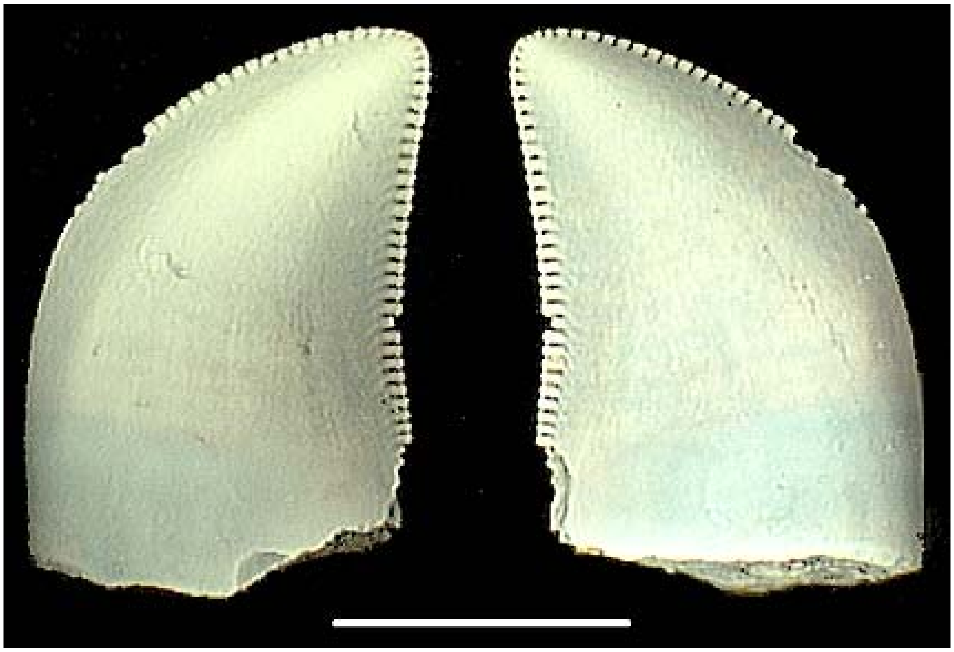


Figure 9.5. Right and left sides of a tooth from a close relative of *Deinonychus*. Note the characteristic backward curvature of the point, and the serrated edges. The scale bar is 5mm.

Robert Broom and Euparkeria

Before the rediscovery of *Deinonychus*, most paleontologists agreed that birds descended from primitive archosaurian reptiles, often referred to as thecodonts, which died out 100 million years before *Deinonychus* walked across southern Montana. Dinosaurs were also traced back to the same ancestor, making birds sort of siblings of dinosaurs. Modern crocodylians, the extinct flying pterosaurs, and other extinct reptilian lines were also thought to have evolved from primitive archosaurs. From then on, however, each lineage split off onto its own separate evolutionary path. Accordingly, dinosaurs, crocodylians, and pterosaurs were classified together in a reptilian group named Archosauria, the "ruling reptiles." Although the common ancestry of birds and archosaurs was acknowledged, birds were placed in a totally separate Class--Aves--to signify that, by evolving feathers, flight, and warm-bloodedness, they had traveled across a far greater distance of evolutionary change than the others.

But putting birds in a separate Class obscured the answer to the principle evolutionary mystery: from which particular lineage of archosaurs did birds descend? This is a difficult problem because when the different lineages are compared to birds, special resemblances are evident with each. For example, birds and pterosaurs both have wings for flight, suggesting to some paleontologists that birds are most closely related to pterosaurs. But, a mosaic of resemblances suggests other possibilities. The feet of birds look much like the feet of dinosaurs, such as *Deinonychus*, having three principal toes that point forward. In fact, the 19th century naturalists who discovered the first dinosaur trackways thought they were the tracks of giant birds. Some paleontologists, like John Ostrom, argue that foot structure provides evidence of close relationship between birds and dinosaurs. Still others features have been identified that seem to link birds to crocodylians, to turtles, and to mammals.

The explanation offered for this confusing mosaic of similarities is that the special resemblances, like the wings and 3-toed feet, evolved separately in the different lineages, a phenomenon known as *convergent* evolution. According to this hypothesis, any special resemblances that birds shared with any of the other archosaurian lineages are the results of convergence, and not evidence of close relationship[2]. This solved many of the problems that arose from conflicting combinations of similarity - they were all independently evolved. Logically, of course, only one archosaur lineages could contain the real ancestor of birds, just like only one person can be your genealogical father or mother, and we'll investigate the “paternity” of birds in upcoming chapters.

This view of avian origins, called the "thecodont hypothesis," sprouted over a century before the name *Deinonychus* was coined, and it has been advocated ever since by a sizable constituency of paleontologists and is the view championed by most ornithologists. At the time, there were several competing views about the relationships among birds and the various archosaurs. But the idea that birds, pterosaurs, and dinosaurs all diverged onto separate evolutionary pathways, grew in popularity toward the end of the 19th and through the first half of the 20th century as more and more fossils came to light from different parts of the world. Around 1910, the discovery of *Euparkeria capensis* (fig. 9.6), by a Mr. Alfred Brown (no relation to Barnum Brown) of Aliwal North[3], a small town along the Orange River of South Africa, solidified the perspective that *Deinonychus* would later threaten.

Figure 9.6. The skull of *Euparkeria capensis*. This specimen is housed in the South African Museum, Cape Town. (Photo courtesy of Jacques Gauthier)

Euparkeria is small, just under a meter from its snout to the tip of its tail (fig. 9.7). It is still among the oldest known archosaurs, dating back to the Early Triassic about 240 million years ago. Both its generalized structure and its antiquity implicate *Euparkeria* in archosaur ancestry. Its teeth are bladelike, serrated and curved, leaving little doubt that *Euparkeria* was predaceous. Its limbs indicate that it usually walked around on all fours--an habitual quadruped. However, the forelimbs are slightly shorter than the hindlimbs, implying that it occasionally ran on its hindlimbs--a facultative biped. Facultative bipedal running the fastest gait in modern reptiles of like proportions, and this was probably the case in *Euparkeria* (fig. 9.8).

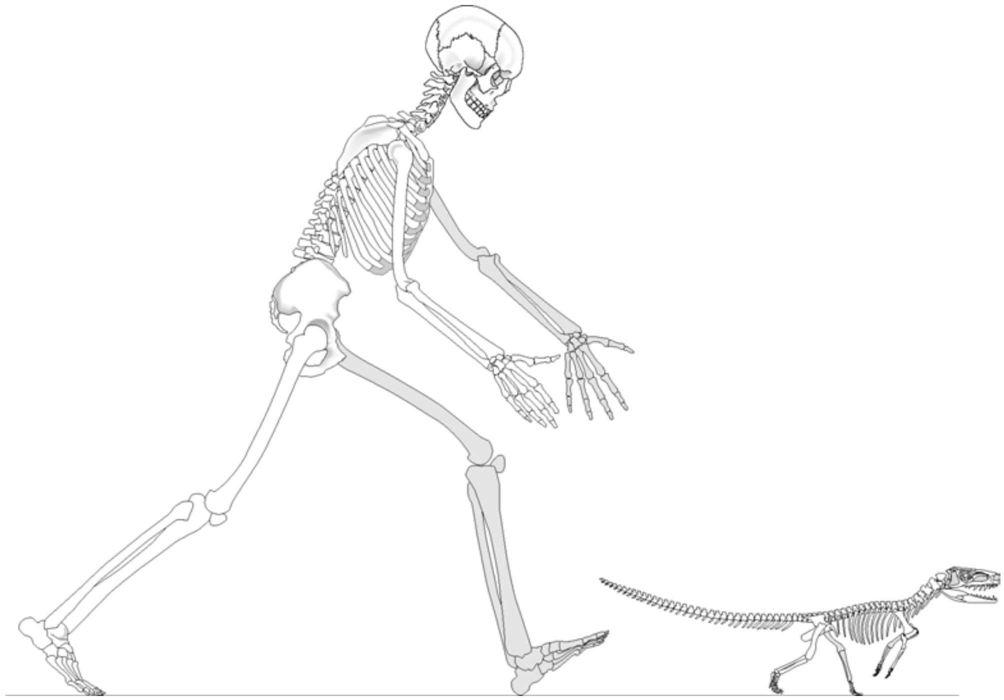


Figure 9.7. *Euparkeria capensis* was about the size of a house cat.

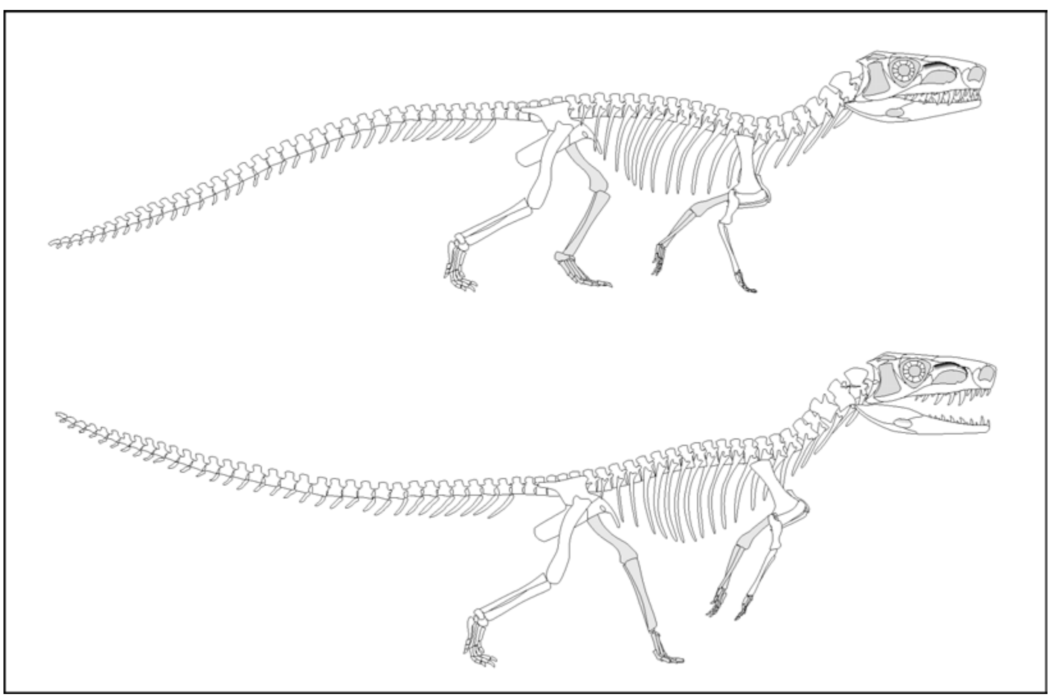


Figure 9.8. *Euparkeria* was an habitual quadruped (top), spending most of its life on all fours. With comparatively short forelimbs, it was also a facultative biped (below), able to run at its highest speeds on its longer hindlimbs alone.

A dozen or so individuals were collected near Aliwal North, but the exact location of their burial site is unknown today. Many paleontologists have searched, but none has found more specimens. Our effective knowledge of this important early archosaur resides in Alfred Brown's original collection, which today is distributed among museums in South Africa, Germany, England, and America[3].

Alfred Brown eventually showed the fossils to Robert Broom (fig. 9.9), South

Figure 9.9. The great South African paleontologist Robert Broom, circa 1950, during a visit to the University of Texas at Austin (photo courtesy of John a. Wilson).

Africa's preeminent paleontologist. Broom immediately recognized that *Euparkeria* was "....very near to the ancestor of the Dinosaurs, Pterodactyles, Birds and Crocodiles, [and] its extreme importance will at once be manifest."[4]. So it was. *Euparkeria*, the primal archosaur, long reigned as the most important discovery of the 20th century in terms archosaur evolution and the origin of birds. In a highly influential book published in 1927, entitled *The Origin of Birds*, Gerhard Heilmann further solidified the view[5]. Since that time, most students have learned that from an ancestor such as *Euparkeria*, over the vastness of Mesozoic time, birds, crocodilians, pterosaurs, and dinosaurs slowly, independently, and divergently evolved (fig. 9.10).

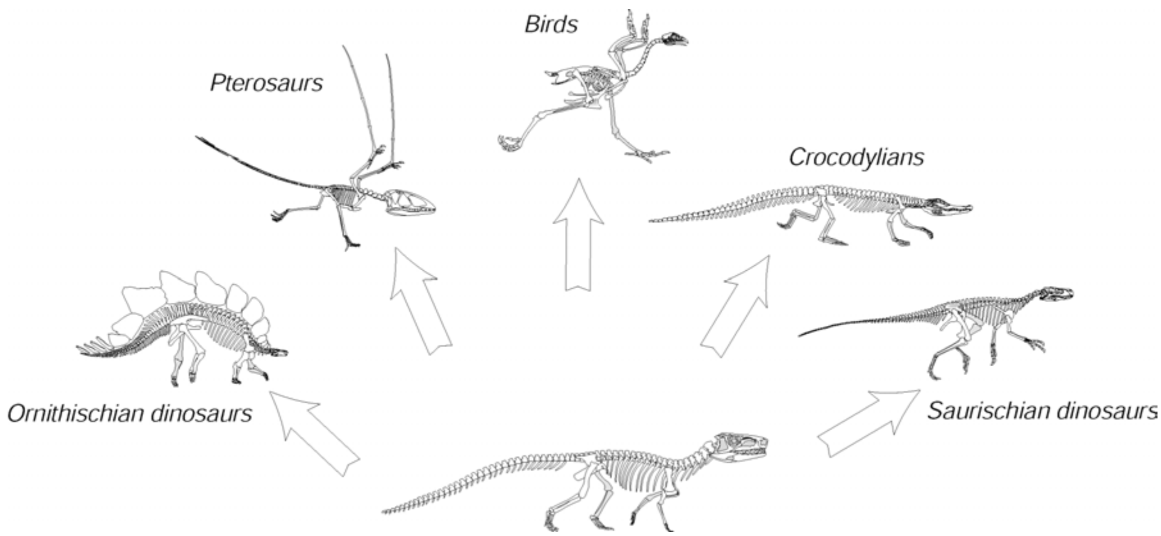


Figure 9.10. According to the popular 20th century “thecodont hypothesis” Euparkeria, or something very much like it, was the ancestor to all these lineages (skeletons not to scale).

From the Trees Down

Identifying *Euparkeria* as a possible ancestor to birds and other archosaurs presented one problem, however. The oldest known bird is 100 million years younger than *Euparkeria*, leaving a long, dark gap of pre-avian history. Paleontologists wondered what the intermediate "protobirds" might have looked like, how they functioned, and behaved. Without fossils, only speculation was possible. Most of the controversy in early avian history revolved around bird's revolutionary new form of locomotion--flight. How did birds evolve flight from ground-dwelling, four-legged ancestors?

Most scientists, Broom included, believed that the ground-living ancestors first moved into the trees (fig. 9.11). These "protobirds" scrambled up tree trunks and along

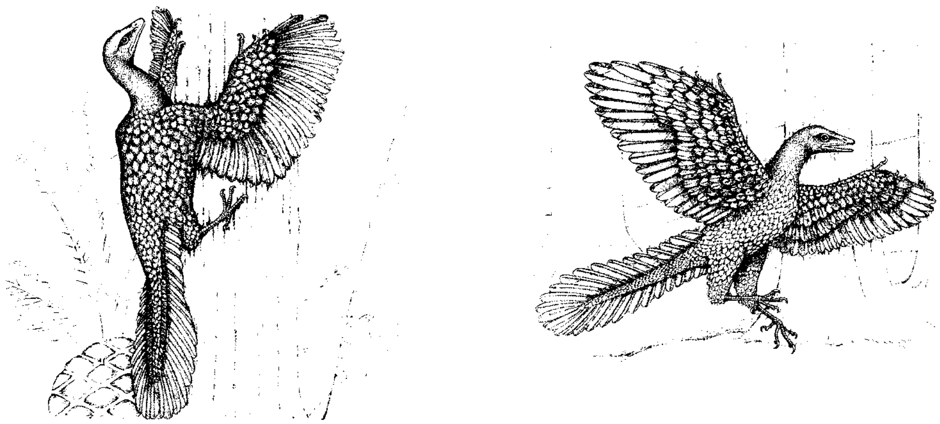


Figure 9.11. Under the thedocont hypothesis, the ancestors of birds are thought to have first moved into the trees and then learned to fly from the trees down. (from Wellnhofer, P., 1990. *Archaeopteryx*, Scientific American, may 1990).

branches using all four limbs, and jumping branch-to-branch much like today's squirrels. To reach the ground to feed, they scampered down the trunks or leapt from low branches. With evolutionary change, "protobirds" began to parachute and then glide down from greater heights. At first, gravity provided most of the power for airborne locomotion, which at this stage was limited to parachuting and gliding. Minor increases in the body's surface area and positioning of that surface improved their gliding ability. To embryologists, feathers are merely modified scales, so *Euparkeria* possessed the evolutionary forerunners of feathers. It only required a selective environment that might lead to their elaboration into feathers, and the trees would seem to provide just that. Gliding eventually led to powered, flapping flight as "protobirds" learned to use their arms more effectively while in the air. Then, the gliders became extinct whereas true birds survived. In essence, flight evolved from the trees down[2].

Although this argument had been around several decades before the discovery of *Euparkeria*, no known fossil could reasonably be interpreted as ancestral to the various archosaurs and birds as well. With Alfred Brown's discovery near the Orange River, the last piece of evidence seemed to be in place.

From the ground up

The "trees down" hypothesis has been compelling to generations of scientists. Intuitively, it would seem that birds *must* have gone through an arboreal stage, and flight *must* have evolved from the trees down. *Deinonychus* came as a rude jolt. It is larger than any modern tree-dwelling bird. Moreover, its skeleton is built for running and taking down prey. *Deinonychus* has long, curved raptorial claws on its hands and feet, including a huge sickle-shaped claw on the end of its second toes for rending flesh, not climbing. Ostrom described the etymology of the name[6] he had coined: "*Deinos* (Greek), terrible, and *onyx* (Greek; masculine), claw or talon." This name does not smack of squirrels scampering through the trees after nuts. If birds are most closely related to dinosaurs like *Deinonychus*, flight must have evolved from the ground up (fig. 9.12).

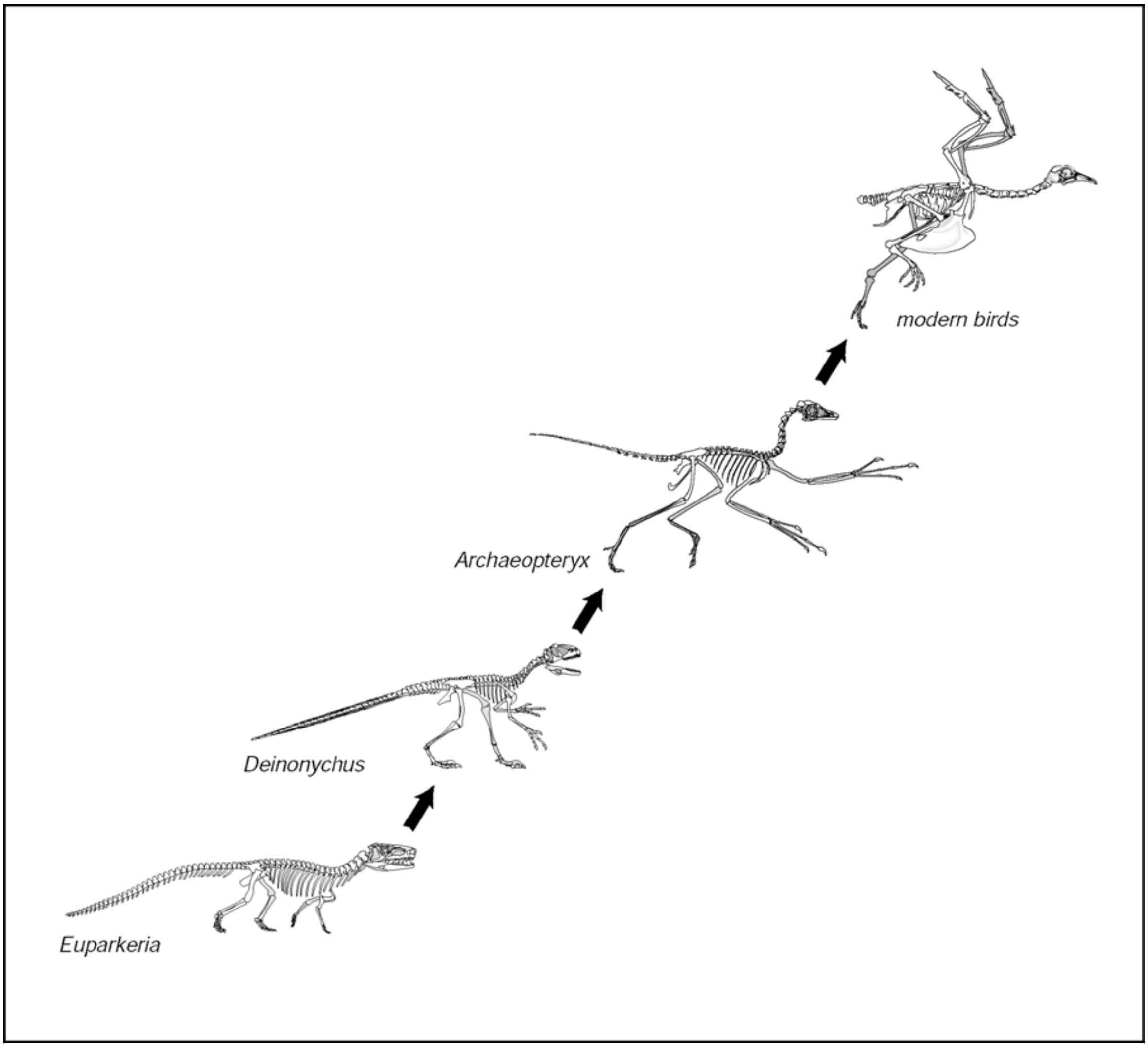


Figure 9.12. According to the "bird-dinosaur hypothesis" flight evolved from the ground up, as birds evolved from extinct dinosaurs like *Deinonychus.*

According to the "ground up" hypothesis, the predatory dinosaurs that were ancestral to birds were fast-running animals that moved on their hindlimbs alone--obligate bipeds--like modern birds. These early dinosaurs also had very powerful forelimbs, like birds do today. The running speed they achieved chasing prey eventually came into play helping them reach speeds necessary to lift off the ground. Throwing their hands forward to rake or grasp for their prey, the ground-dwelling dinosaurs performed an action that was the precursor of the flight stroke. The elaboration of scales into feathers--even small feathers--may convey greater maneuverability in chasing prey over broken ground. Even a small increase in the surface area of the forelimb might provide some lift, and greater degrees of lift could be generated as the powerful limbs swiveled rapidly forward through the air. The act of catching fleeting prey eventually led to the evolution of powered, flapping flight, as the hands and arms of bipedal dinosaurs became elongated and as flight feathers evolved.

For most people, it was hard to imagine how flight could have evolved through intermediate stages from the ground up, where at some point, the forelimbs must have been transitional between the arms of predatory dinosaurs and the wings of a fully flying bird. The thought of a partly volant bird was like the thought of being partly pregnant. Nevertheless, Ostrom argued that the discovery of *Deinonychus* provided evidence that flight evolved from the ground up[7].

Archaeopteryx: the oldest known bird

Before even attempting to explain how flight might have evolved from a dinosaur, John Ostrom first had to test whether a close evolutionary relationship really existed between *Deinonychus* and birds. If not, then there was no point in trying to explain how flight evolved from the ground up. The logical place to start was by comparing *Deinonychus* to the oldest known bird, *Archaeopteryx lithographica*. In the process, Owen made several more significant rediscoveries.

To museum curators the name *Archaeopteryx* rings like that of Rembrandt, Stradivarius, or Michelangelo. *Archaeopteryx* is known from the world's most celebrated, controversial, valuable, and rare fossils. The importance of *Archaeopteryx* rests upon its antiquity of 150 million years, the transitional nature of its skeleton, and the timing of its discovery, which occurred only two years after Darwin's *The Origin of*

Species was published. The peerless preservation of the specimens, one a single, perfect feather (fig. 9.13), has further enhanced their importance and mystique.

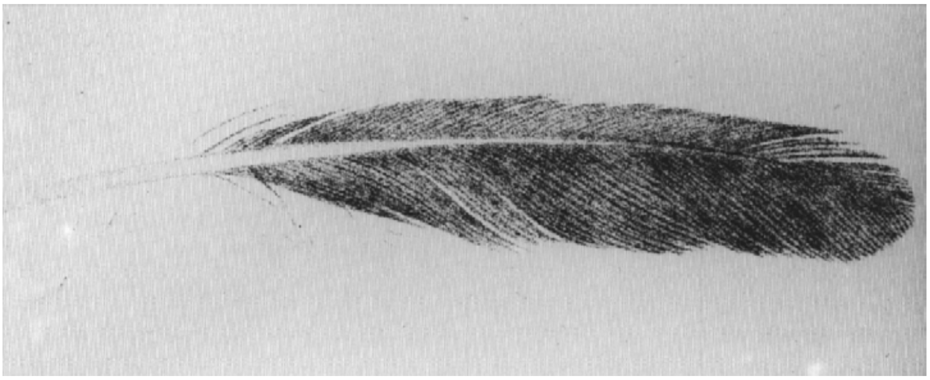


Figure 9.13. Hermann von Meyer's lithograph of the single feather of *Archaeopteryx*. (from Meyer, Hermann, von 1862a. *Archaeopteryx lithographica* from the Lithographic Slate of Solenhofen. Annals and Magazine of Natural History, London, 9: 366-370).

In addition to the exquisite but uninformative feather, only seven specimens of *Archaeopteryx* are known. Each preserves some or all of the skeleton, along with feather impressions that are more or less obvious. Each is named according to its proprietor or place of discovery. The first skeleton to be discovered is now in England, the London *Archaeopteryx*, arriving in 1862 to become the center of historic debates about evolution that erupted into scientific and public forums with publication of *On the Origin of Species*. Consequently, it is considered a "Crown Jewel." Four specimens are in Germany and one is in the Netherlands, where they are similarly acclaimed. The seventh specimen has vanished.

<u>*Solnhofen*</u>

All known specimens of *Archaeopteryx* were collected from stone quarries in the Solnhofen Limestone, located in Bavaria's Franconian Alb region of southern Germany. The limestone outcroppings were exposed by erosion of the Altmühl River. The quarried stones were famous for their marble-like beauty centuries before their fossils were appreciated by the scientific community. Romans first used them for buildings and road-paving. Since then, they have been widely valued as ornamental building materials, and they adorn centuries-old palaces and modern state buildings throughout Europe and the world.

The unusual setting in which these rocks formed is responsible for both their fine building attributes and their exquisite rare fossils[9]. During the Late Jurassic, Bavaria was covered by a shallow sea. Across the arid Altmühl region was a tropical or sub-tropical lagoon. The lagoon's floor was composed of a chain of basins divided by reefs and shell mounds that restricted water circulation. The bottom water was probably stagnant, very salty and devoid of oxygen, except when flushed out by occasional storm surges. A steady rain of microscopic shells produced by plankton living in the surface waters filtered down onto the quiet basin floors, burying whatever else had drifted in. That limy ooze later turned to rock, petrifying the carcasses of *Archaeopteryx*, pterosaurs, crabs, insects, shrimp, crinoids, and a diversity of fishes. Because the bottom waters lacked oxygen, the usual diversity of scavenging and bottom-feeding creatures was absent. Cadavers deposited on the floor of the lagoon remained undisturbed, producing some of the world's most spectacular fossils with intricate impressions of skin, feathers, and other soft tissues.

An emerging local technology in the 18th century catalyzed the discovery of the first *Archaeopteryx* specimens about 100 years later. In the town of Solnhofen, for which the limestone beds were named, Alois Senefelder invented the process known as lithography, using slabs of rock taken from near-by quarries in the Solnhofen Limestone[9]. Lithography enabled the first mass-publication of illustrations. For many decades it was the principal method for reproducing imagery, fostering a thriving business in the Altmühl district. In the lithography process, an image is rendered onto a flat surface and treated so that it will retain ink, while the non-image areas are treated in a fashion that repels ink. Once inked, detailed images can be printed by pressing or rolling paper onto the stone. Any flaw, such as a fossilized shell or bone, mars the printing surface, rendering the stone unsuitable for lithography. The Solnhofen stone quarries produce some of the world's finest lithographic stones and command high prices even today, although lithography may be a dying art.

Discovery of the first *Archaeopteryx* specimens occurred near the peak of demand for lithography stones. Looking for stones with perfect surfaces, each slab of limestone was chiseled from the quarry by hand and checked for blemishes. The stones were then set aside for lithography or trimmed into shingles, floor tiles, and so on. For two centuries, workers have also set aside slabs with fossils, owing to their growing commercial value. As quarrymen inspected untold thousands of Solnhofen slabs, eight specimens of *Archaeopteryx* have been found.

<u>*The Eight Specimens*</u>

The first *Archaeopteryx* specimen recognized to be a bird was the perfectly preserved impression of a single feather found in 1860. Early the next year, Dr. Hermann von Meyer, a preeminent paleontologist from the Senckenberg Natural History Museum, published a short report, announcing the unprecedented discovery of a Mesozoic bird. He quickly followed with another publication that included an illustration--a lithograph--showing the unmistakable resemblance of this ancient fossil to the flight feathers of modern birds (fig. 9.13). His announcements raised a rumble of controversy. The authenticity and age of the fossil were immediately questioned. But a few months later the discovery of the first skeleton (fig. 9.14a,b) temporarily put to rest the question of

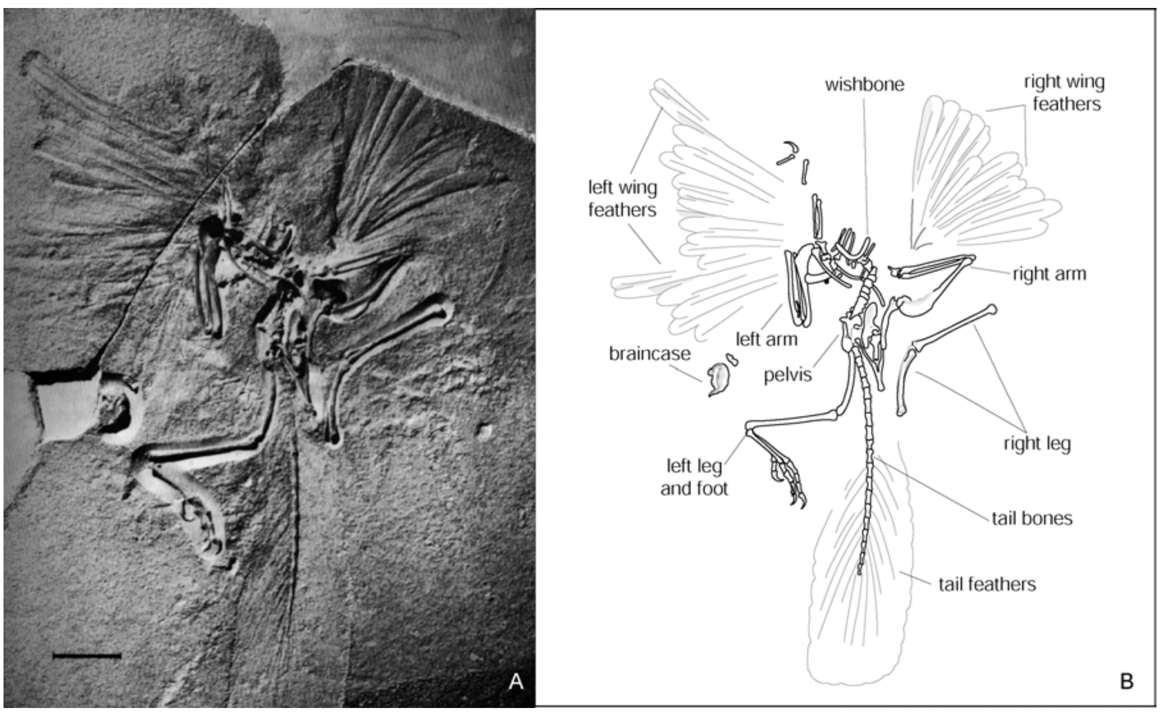


Figure 9.14. The London specimen of *Archaeopteryx*, housed in the British Museum (Natural History). A: photo of the main slab (photo by Jacques Gauthier), and B) a drawing of the specimen as preserved.

authenticity. Most of the skeleton was preserved, along with impressions of the feathers radiating fanwise from each of the forelimbs and along each side of the long bony tail. In that same year in which he had announced the feather, von Meyer published a two-page announcement of the first skeleton of a Mesozoic bird. For this specimen, he coined the name *Archaeopteryx lithographica*, the root "*archaios* " meaning ancient and "*pteryx* " meaning wing. The species name, *lithographica*, refers to the lithographic limestone in which it was buried and the state of its preservation. By the end of the year, von Meyer's short announcements had grabbed the attention of the scientific community[8].

The hype surrounding this skeleton was promoted by its first owner, Dr. Karl Häberlein, a medical officer for the district of Pappenheim. Häberlein was a collector who accepted the fossil in payment for his medical services. He appreciated the potential value of such an ancient and well preserved bird. He let several people inspect it, but no one could make drawings or take photographs. One visitor did make a drawing from memory shortly after viewing the specimen, fueling speculation about the specimen's importance and raising its value. Häberlein offered the specimen for sale at, probably, the highest price yet asked for a fossil, some £750[10]. A scramble for the fossil bird ensued. The German court tried to secure it for the State Collection in Munich, but the British Museum succeeded in negotiating Häberlein's unprecedented final price of £700. The Museum's payment for this and other fossils in Häberlein's collection had to be spread across two fiscal years. The slab and counter slab became known as the London *Archaeopteryx*.

A century later, Dr. Alan Charig was the Curator at the British Museum in charge of the London *Archaeopteryx*. Charig regarded it as the most valuable fossil in both the museum and the world. Although the museum usually displays real specimens, only a cast of *Archaeopteryx* is exhibited for safety, and the museum avoids publicly divulging exactly where the original is stored in the museum[12].

A third, even more extraordinary *Archaeopteryx* specimen was discovered in the fall of 1876[12]. This skeleton is virtually complete and posed in a natural death-posture, with feather impressions spreading out from the forelimbs and tail. It came from a quarry near Eichstätt about 15 km from where the London specimen was found and was acquired by Dr. Ernst Häberlein, the son of Karl. Ernst sold the specimen in 1881, this time to The Museum for Natural History of Humboldt University in Berlin, for £1000[10]. The Berlin *Archaeopteryx* is the most complete and exquisitely positioned of all the specimens found to date (fig. 9.15a, b). Unlike the London specimen, the Berlin skull remains attached to the neck. It has teeth in the jaws instead of a beak. Parts of the head and teeth were later recognized on the London specimen, but the Berlin *Archaeopteryx* is still the most complete.

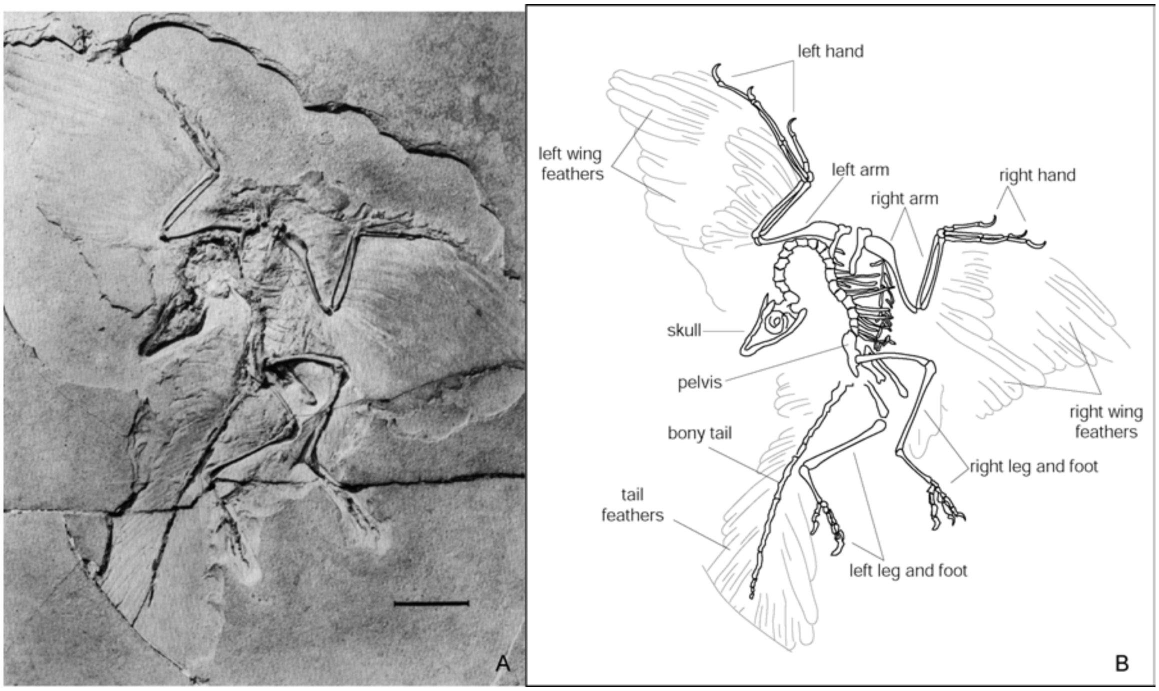


Figure 9.15. The Berlin specimen of Archaeopteryx, how housed in the Humboldt University Museum of Natural History. A) Photo of the main slab (photo by Jacques Gauthier), and B) a drawing of the specimen as preserved.

Eight decades passed before the fourth *Archaeopteryx* specimen was recovered in 1956, from a quarry near the discovery site for the London specimen. It was quickly identified and described as a new specimen of *Archaeopteryx* in 1959 by Florian Heller[13], a paleontologist from Erlangen University. It was privately owned by a Mr. Eduard Opitsch and exhibited for two decades at the Maxberg Museum near Solnhofen. For a time, the Maxberg *Archaeopteryx* was accessible to researchers, including John Ostrom.

When Ostrom began his comparison of *Deinonychus* and *Archaeopteryx*, only the London, Berlin, and Maxberg skeletons, along with the single feather, were known. While touring European museums to study them, Ostrom looked at other fossils collected from the Solnhofen limestone. Naturally, he was also interested in pterosaurs, another group of extinct flying vertebrates. This interest led him to the Teylers Museum in Haarlem, the Netherlands, to examine a specimen that had been collected in 1855 and described in 1857 as a new species of pterosaur[14]. The author was none other than Hermann von Meyer, who would four years later coin the name *Archaeopteryx* *lithographica*. Pterosaurs were well-known from the Solnhofen limestone by the mid-nineteenth century. Perhaps because it was incomplete, the true identity of this specimen went unrecognized until 1970, when Ostrom peered into its storage cabinet [15]. Ostrom realized that Meyer had actually described the first *three* specimens of *Archaeopteryx*.

The sixth and seventh specimens also sat unrecognized for many years after they were first discovered. The sixth is a complete, articulated skeleton that was misidentified as the contemporary dinosaur *Compsognathus*, which is about the same size as *Archaeopteryx*. It was collected in 1951 but not recognized to be *Archaeopteryx* until 1970. Franz Mayr of the University of Eichstätt, illuminated the specimen with oblique lighting and was the first to see faint feather impressions along the tail and arms[16]. The Eichstätt *Archaeopteryx* is exquisite and has the best skull of the lot. The seventh specimen was also misidentified as *Comsognathus* for many years after it was collected. Its amateur collector failed to keep record of exactly where near Eichstätt he found it. In 1987 the curator of the Jura Museum, Gunter Viohl, recognized this seventh *Archaeopteryx* in the private collection of Freidrich Müller, a former mayor of Solnhofen. It now belongs to the village and is on display in the Burgermeister Müller Museum. The Solnhofen *Archaeopteryx* is quite complete, and its bones remain in their natural positions, although some critical parts of the skull were lost during excavation or preparation.

The most recent and eighth discovery of an *Archaeopteryx* specimen was made in 1992 from near the sites of the London and Maxberg specimens[17]. It is larger than the other skeletons and preserves a number of important anatomical details not previously seen. So long as the Solnhofen quarries are worked with current techniques, a new specimen of *Archaeopteryx* will probably be unearthed every decade or so (fig. 9.16).

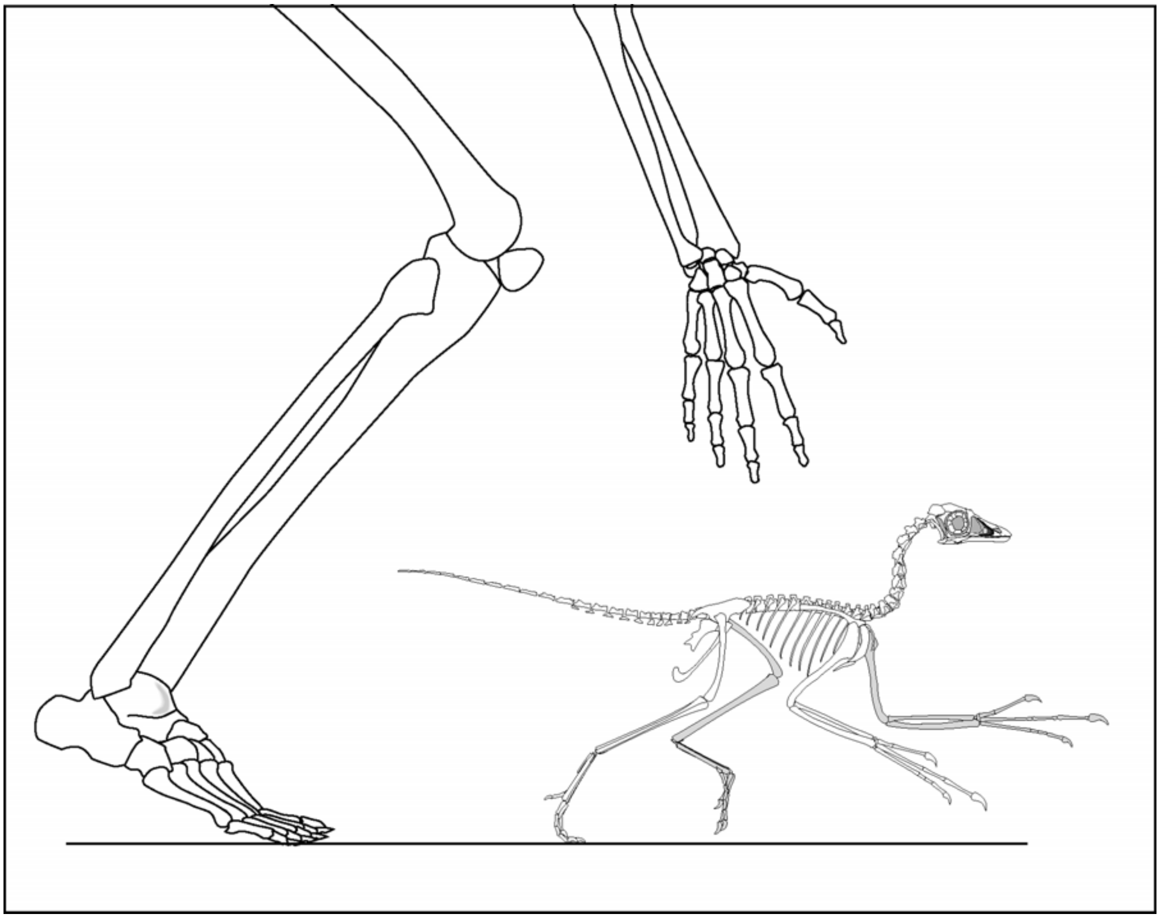


Figure 9.16. The skeleton of the 140 million year old bird, *Archaeopteryx lithographica*, compared to the arm and leg of modern *Homo sapiens*, for scale.

<u>*Theft?*</u>

Tragically, in 1982, Eduard Opitsch, owner of the Maxberg *Archaeopteryx,* removed it from display and took it to his home. Until his death in 1991, he refused scientists access to the specimen. Opitsch even ignored a request to borrow the specimen briefly for the 1984 International *Archaeopteryx* Conference in nearby Eichstätt organized by Dr. Peter Wellnhofer, a preeminent authority on *Archaeopteryx* and director of the nearby Bayerische Staatssammlung fur Paläontologie in Munich. Wellnhofer wanted to gather together all of the *Archaeopteryx* specimens and all of the *Archaeopteryx* experts in one place. Sadly this unprecedented and distinguished conference went off without the Maxberg specimen. Opitsch died a bachelor at the age of 91. Immediately after his death, his nephew and only heir tried to locate the specimen, but failed. There is no evidence that Opitsch sold the specimen. German authorities handling the case believe that someone carried off the Maxberg *Archaeopteryx* in the commotion of activity that had attended Eduard Opitsch's death. Wellnhofer has notified the scientific community of the disappearance[18], but its whereabouts remain unknown.

Fraud?

An unexpected challenge to *Archaeopteryx* came from a famous physicist in 1986. Sir Fred Hoyle and Chandra Wickramasinghe, otherwise respected for their works on astronomy and mathematics, published a book entitled *Archaeopteryx, the Primordial Bird: A Case of Fossil Forgery*[19]. Their writings and public presentations attracted considerable interest. With one author knighted, considerable clout accompanied their challenge.

Hoyle and Wickramasinghe claimed that the London specimen is an authentic *Compsognathus*, but that the feather impressions were faked to perpetrate a hoax, in support of Darwin's false theory evolution. *Archaeopteryx*, like the famous Piltdown Man hoax in which altered modern ape bones were planted together with some authentic specimens, had fooled paleontologists for about 50 years. And Hoyle and Wickramasinghe asserted that the scientific world has been fooled by *Archaeopteryx* for even longer.

These authors alleged that limestone, gouged from around the bones of a genuine *Compsognathus* skeleton, was later poured back into the gouges as a limestone cement and, while still wet, modern feathers were pressed into it. Voilà, a dinosaur with feathers. The forger was the original owner, Dr. Karl Häberlein, who sought to augment the specimen's value. Richard Owen, who orchestrated the specimen's purchase from Häberlein, knew of the forgery and in fact had probably commissioned it himself. Owen may even have arranged the untimely death of Andreas Wagner who published a notice shortly before his death questioning the authenticity of the specimen. Owen, a life-long opponent of evolution, planed to reveal the fraud and discredit the evolutionists.

Inexplicably, the trap was never sprung. Nevertheless, Hoyle and Wickramasinghe allege that subsequent generations of British paleontologists have conspired to maintain the hoax, in a desperate attempt to prop up Darwin's flawed theory of evolution. These authors' preferred evolutionary theory is that viral invasions from outer space periodically introduce new genes into the chromosomes of living organisms.

So, evolution proceeds in sudden bursts, and transitional forms, like *Archaeopteryx*, must be bogus.

Alan Charig, curator of the London *Archaeopteryx*, must have relished his chance to respond[14]. Working with technicians, he detailed the many properties of the specimen that would have to have been faked. Indeed, the specimen preserves so much detail that the accomplishment of producing a convincing fake would be far more remarkable than the conspiracy itself. Most important would be to match hairline fractures that crosscut both slabs and which were, therefore, made before the slab and counterslab were split. In addition, the impressions of bones and feathers match exactly on the slab and counter slab, so they could only have been made before the split. There is no evidence of a secondary infilling of cement. Charig summarized the charges as "based on a plethora of faulty observations, incorrect data, wrong interpretations, untrue statements and misleading arguments; which, in turn, are due to sheer carelessness, lack of knowledge of the relevant subjects, false logic and a fertile imagination."[20] The charge that *Archaeopteryx* is a fraud is as believable as the "constipation cause" for extinction. The authenticity of the eight *Archaeopteryx* specimens is one of the very few points that everyone else on both sides of the bird-dinosaur debate can agree upon.

<u>*Deinonychus and Archaeopteryx Compared*</u>

During his European trip, Ostrom noted that the limbs of *Deinonychus* and *Archaeopteryx* exhibited many unique resemblances[7]. Animals with four limbs are called tetrapods (tetra=four, pod=feet), and these include birds, dinosaurs, humans, lizards, crocodilians, turtles, and many others. As we will see, evolution has produced many variations on a central pattern of bones that underlies the skin in all tetrapod limbs.

The tetrapod forelimb contains a string of bones that extend from the shoulder to the fingers (fig. 9.17). Between the shoulder and the elbow is a single bone, the *humerus*.

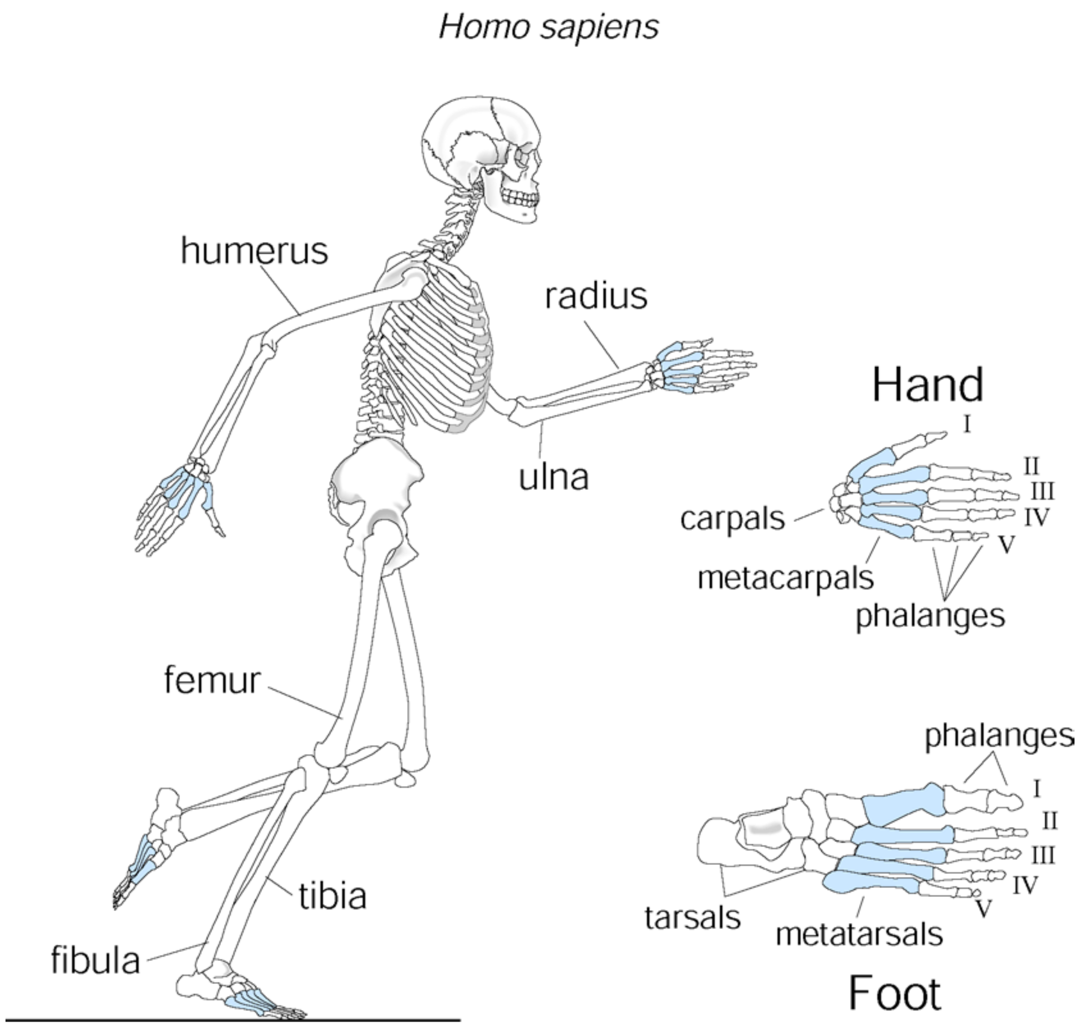


Figure 9.17. In virtually all tetrapods, the forelimb contains a consistent pattern of bones that extend from the shoulder to the fingers.

Between the elbow and the wrist are two bones, the *radius*, which lies on the inside or thumb side of the forearm, and the *ulna*, which lies on the outside or "pinkie" side. The arrangement is the same in all tetrapods, except some, like snakes, who lose their forelimbs altogether. The bones of the wrist called *carpals*, however, vary in number and shape. There were originally probably eight, but they have been variously lost, fused, and otherwise transformed in different tetrapod lineages. Next, the bones forming the palm of the hand are referred to as *metacarpals*, and there are usually five of them--one for each finger. The fingers are made from numerous *phalanges* (*phalanx* is the singular).

Ostrom noted that both *Archaeopteryx* and *Deinonychus* have an unusual three-fingered hand, in which the thumb, digit I, is the shortest and the index finger, digit II, is the longest. Most reptiles, like humans, have five fingers. In *Deinonychus*, there is also an unusual half-moon-shaped bone in the wrist--the *semilunate carpal*. This bone's shape helps to direct the peculiar swivel path the hand of a bird takes during the flight stroke, and it is present in *Archaeopteryx*. Might this swivel-wrist be evidence for a close evolutionary relationship?

There are also unique resemblances between them in the hindlimb. The hindlimb is built much like the forelimb in tetrapods. The *femur* or thigh bone extends between the hip socket and the knee. Between the knee and ankle, the *tibia* or shin bone runs along the inside side, whereas a more slender bone, the *fibula*, lies on the outside. In birds, the fibula tapers to a point a short distance below the knee and fails to reach the ankle, a very distinctive configuration. The ankle bones, or *tarsals*, like the bones of the wrist, are numerous and complex. The foot is made up of the *metatarsals*, which extend between the tarsals and each toe, and there is a variable number of *phalanges* in each toe.

In both *Archaeopteryx* and *Deinonychus* (fig. 9.18) the outer toe, digit V, has been lost, and the inner toe or first digit, the *hallux*, is shortened. The principal toes, digits II, III, and IV are arranged symmetrically about digit III, which is the longest. Ostrom argued that these resemblances are unique, and that they point to a close evolutionary relationship between birds and dinosaurs.

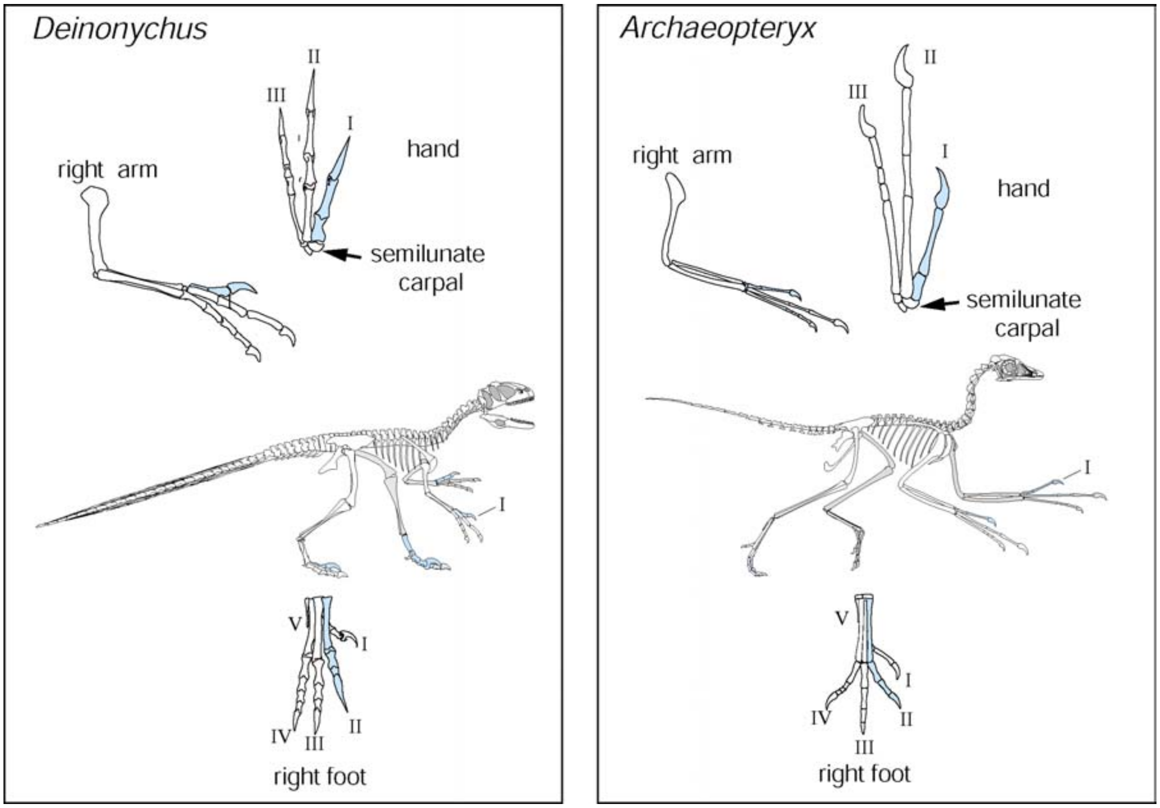


Figure 9.18. The limbs of *Deinonychus* and *Archaeopteryx* compared.

<u>*Still no consensus*</u>

Still, there were problems that Ostrom's bold hypothesis did not explain. *Deinonychus*, the bird-like dinosaur thought to resemble the ancestor of birds, lived tens of millions of years *later* than *Archaeopteryx*. So, *Deinonychus* could not be ancestral to birds, and no other dinosaur was thought to share all the unique features pointing to a resemblance with birds. In addition, critics pointed to unique resemblances between birds and other reptiles. For instance, both birds and pterosaurs have tubular skeletons made up of thin-walled, hollow bones, and the braincase of *Archaeopteryx* resembles crocodilians. And what about the origin of flight? How could it have evolved from the ground up?

By the time our first semester at Berkeley ended, there was still no clear resolution to the argument about "trees down" versus "ground up" origin of birds. Who were the ancestors of birds? Were they dinosaurs or undiscovered tree-dwelling reptiles? Nonetheless, something else was becoming clear. The debate that Ostrom carried to our generation was not new. Virtually the same battle had been fought a century-and-a-half ago in Victorian England, between Darwin and the critics of his theory of evolution. Like the rebirth of catastrophism that occurred with the discovery of Iridium, we watched a 19^{th} century drama replayed in Berkeley's Paleontology Department. Ostrom's proposed connection between birds and Mesozoic dinosaurs was yet another rediscovery. And this storm of controversy, like the first one, violently tore at some large branches on the tree of life.

Notes and References for Chapter 9

1) Ostrom, J. H., 1969. Osteology of *Deinonychus antirrhopus*, an unusual theropod from the Lower Cretaceous of Montana. Bulletin, Peabody Museum of Natural History, 30: 1-165.

2) Feduccia, A., 1996. The Origin and Evolution of Birds. New Haven, Yale University Press.

3) Ewer, R. F., 1965. The anatomy of the thecodont reptile *Euparkeria capensis* Broom. Philosophical Transactions of the Royal Society of London, series B, 248: 379-435.

4) Broom, R., 1913a. Note on *Mesosuchus browni*, Watson and on a new South African Triassic pseudosuchian. Records of the Albany Museum, 2(5): 394-396; Broom, R. 1913b. On the South African pseudosuchian *Euparkeria* and allied genera. Proceedings of the Zoological Society, London, 619-633.

5) Heilmann, G., 1927. The Origin of Birds. New York, D. Appleton.

6) Ostrom, J. H., 1969. A new theropod dinosaur from the Lower Cretaceous of Montana. Postilla, 128:1-17.

7) Ostrom, J. H., 1973. The ancestry of birds. Nature, 242: 136; Ostrom, J. H., 1974. *Archaeopteryx* and the origin of flight. Quarterly Review of Biology, 49: 27-47; Ostrom, J. H., 1975. The origin of birds. Annual Reviews of Earth and Planetary Sciences, 3: 55-77; Ostrom, J. H., 1976. *Archaeopteryx* and the origin of birds. Biological Journal of the Linnean Society of London, 8: 91-182; Ostrom, J. H., 1979. Bird flight: How did it begin? American Scientist, 67: 46-56; Ostrom, J. H., 1994. On the origin of birds and of avian flight. Pp. 160-177 in: Major Features of Vertebrate Evolution, D. R. Prothero and R. M. Schoch (eds.), Short Courses in Paleontology No. 7, University of Tennessee, Knoxville.

8) Meyer, H. von, 1861a. Vogel-Ferden und Palpipes priscus von Solenhofen. Neues Jharbuch Min. Geol. Palaont., Stuttgart, 1861: 561; Meyer, H. von, 1861b. Archaeopteryx lithographica aus dem lithographischen Schiefer von Solenhofen. Palaeontographica 10:53-56, 1 plate; Meyer, H. von, 1861b. *Archaeopteryx lithographica* (Vogel-feder) und *Pterodactylus* von Solenhofen. Neues Jahrbuch für Mineralogie, Geologie und Paläontologir, Stuttgart, 1861: 678-679; Meyer, H., von, 1862a. On the *Archaeopteryx lithographica* from the Lithographic Slate of Solenhofen. Annals and Magazine of Natural History, London, 9 (third series): 366-370.

9) Barthel, K. W., N. H. M. Swinburne, and S. Conway Morris, 1990. Solnhofen: A study in Mesozoic Palaeontology. Cambridge, Cambridge University Press;

Ostrom, J. H., 1991. Solnhofen: A study in Mesozoic Palaeontology. Journal of Vertebrate Paleontology, 11: 528-529.

10) deBeer, G. R., 1954. *Archaeopteryx lithographica*; a study based on the British Museum specimen. London, British Museum, publication 224; Owen, R., 1863. On the *Archaeopteryx* of von Meyer, with a description of the fossil remains of a long-tailed species, from the lithographic stone of Solenhofen. Philosophical Transactions, Royal Society of London, 153: 33-47.

11) pers. Comm. to TR 9/75; the specimen is of course accessible to researchers and other interested parties by appointment with curatorial staff of the Natural History Museum.

12) Wellnhofer, P., 1990. *Archaeopteryx*. Scientific American, May 1990: 70-77.

13) Heller, F., 1959. Ein dritter *Archaeopteryx*-Fund aus den Solnhofener Plattenkalken von Langenalthein/Mfr. Erlanger Geologische Abhandlungen, 31: 3-25.

14) Charig, A., F. Greenway, A. C. Milner, C. A. Walker, and P. J. Whybrow, 1986. *Archaeopteryx* is not a forgery. Science, 232: 622-626.

15) Ostrom, J. H., 1970. *Archaeopteryx*: notice of a new specimen. Science, 170: 537-538.

16) Mayr, F. X., 1973. Ein Neuer *Archaeopteryx*-Fund. Paleontologisches Zeitschrift, 47: 17-24.

17) Wellenhofer, P., 1988. A new specimen of *Archaeopteryx*. Science, 240: 1790-1792; Wellenhofer, P., 1993. Das siebte Exemplar von *Archaeopteryx* aus den Solnhofener Schichten. Archaeopteryx, 11: 1-48.

18) Wellenhofer, P., 1992. Missing *Archaeopteryx*. News Bulletin, Society of Vertebrate Paleontolgy, 155: 53-54.

19) Hoyle, F., and C. Wickramasinghe, 1986. *Archaeopteryx*, the Primordial Bird: a case of fossil forgery. London, Christohper Davies.

20) Charig, A., 1986. Unnatural Selection. Science, 233: 1213-1214.