

Dinosaur Reproduction: Myths and Facts

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The study of dinosaur reproduction is still an immature science. Although we have begun to understand something about mating, egg laying and growth, there is still much that we do not know.

Dinosaurs reproduced. Honest!

Although no one has seen dinosaurs reproducing (the BBC's *Walking With Dinosaurs* is the closest we shall ever come), we do have indirect evidence: their eggs and embryos, and the fact that all vertebrates today reproduce, therefore, as vertebrates, it is safe to assume dinosaurs did too.

Modern vertebrates provide important but indirect clues about the

possible behavior of dinosaurs. For example, graveyards containing only a single species of dinosaur suggests herding, much like antelopes in the Serengeti today (Carpenter, 1999). Herding animals have elaborate social structures, especially involving mating behavior. Furthermore, certain pathologies, such as fractured bones, show that some dinosaurs got into fights, possibly during the mating season. We can image males of the dome-headed *Stygimoloch* butting into each other, as they grunted and

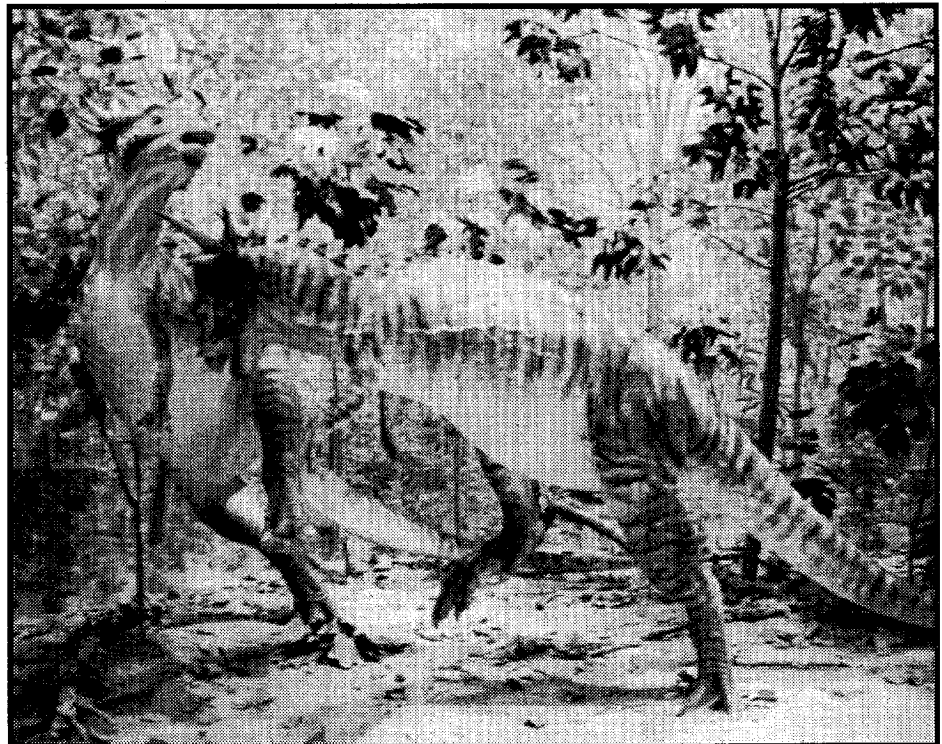
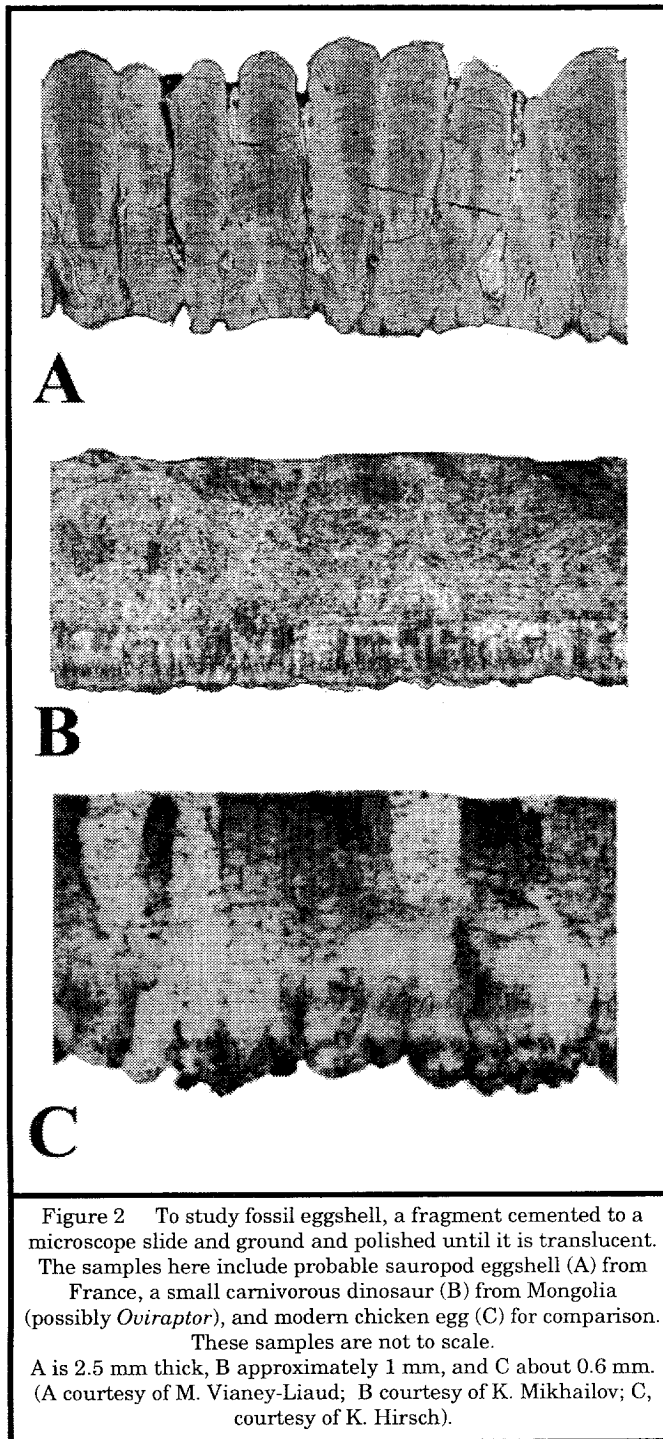


Figure 1 The mating season during the Age of Dinosaurs must have been a very loud time as males sparred for females. Here two rival dome-headed *Stygimoloch* engage in body butting. The winner gets the female, who is watching from the nearby undergrowth. (Life-size diorama at the Denver Museum of Natural History).

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grew, and trampled the vegetation (Figure 1). But not all dinosaurs necessarily fought. We know from new discoveries from China, that some small carnivorous dinosaurs had feathers (Ackerman, 1998). Considering how bird-like some of these small dinosaurs were in their anatomy, they may have used their feathers in bird-like displays: the cluster of feathers

the fertilized egg descends down the oviduct one at a time and passes through several glands (Taylor, 1970). The yolk is the first structure added. It provides the developing embryo with a concentrated, nutrient-rich food source. Around the yolk and embryo, the egg "white" is secreted as a series of layers. Among the many roles of the egg white, or albumin, is

at the end of the short tail of *Caudipteryx* may have been spread off in peacock fashion.

The displays, which may have also included head-bobbing and strutting, as well as fights, were probably important in the lives of the dinosaurs. This social behavior was undoubtedly seasonal and timed so that mating, egg laying and incubation, resulted in hatching when food availability was at its peak. So, how was mating achieved? Most likely the female squatted like a cat, moved her tail to one side as much as she could and the male mounted from behind and one side (Carpenter, 1999)

Which method dinosaurs utilized is actually known for one dinosaur. *Sinosauropteryx* is a small carnivorous dinosaur from China. Near the pelvis, where the oviducts would be in birds, is a pair of eggs next to each other. No other eggs are present, so egg production is not reptile-like, but is bird-like. Not surprisingly, the microscopic structure of the eggshell is very similar to that of birds. Does this mean that all dinosaurs had bird-like egg production? Considering how diverse dinosaurs are, we cannot extrapolate in such a manner. There is some indirect evidence suggesting that some dinosaurs may have had a more reptilian-style of egg production. This evidence is seen in clutches of eggs that appear to have been dumped into a hole, much like sea turtles do on a beach (Carpenter, 1999). As we might expect, the microscopic structure of these eggs is unlike bird eggshell (Figure 2). All of this evidence suggests that the egg layer (possibly a sauropod, or 'brontosaurus'-like dinosaur), had the more primitive, reptile-type reproduction.

The sperm migrated to the top of the oviduct where they fertilized the eggs. In modern birds,

to act as a shock absorber to prevent damage to the delicate embryo. Next, the egg moves towards the shell gland, but just before getting there, the shell membrane is added. This membrane envelops the egg white and yolk to keep it from running (the shell membrane is the "skin" that lines the inside of a shell). The shell membrane also provides a surface for the shell to be deposited. The shell, made of calcium carbonate (same mineral that forms sea shells and limestone), is "sweated" onto the membrane by the shell glands. As each egg is formed, it is laid. Reptiles, on the other hand, produce an entire clutch at one time. The eggs descend down the oviduct like a chain of beads, with egg production assembly line fashion. The eggs are held in a structure called the cloaca, and are all laid at the same time.

So, what do we know about dinosaur nests? Actually, very little. It is important to distinguish between a clutch of eggs and a nest. Among living animals today, a nest may be a simple hole dug in the sand (e.g., sea turtle), a mound of mud and vegetation (crocodiles) or an elaborately weaved structure of twigs and grass

(e.g., nests of many tree dwelling birds). With dinosaurs, we don't really know what their nest structures were in all cases. The pastoral scene (Horner and Gorman, 1988) of baby dinosaurs crawling out of a circular depression filled with vegetation that had been lovingly collected by the mother is a myth (sorry). In truth, all traces of the vegetation (if it was even there) are long gone. In several instances, the evidence suggests that the eggs were laid in shallow holes dug in the ground (e.g., sauropod eggs) and in others the eggs were apparently laid directly on the ground ostrich-style (*Oviraptor* eggs) (Figure 3). It is possible that *some* dinosaurs buried their eggs in mounds of vegetation, but at the present we cannot be sure. Groups of dinosaur eggs are therefore

more appropriately called a clutch, not a nest of eggs. A clutch of eggs may assume several different shapes, including close-packed clumps, rings, or multiple layers.

Because we know so little about dinosaur nests, it follows that we know very little about parental care. Keep in mind that behavior is intangible: it cannot fossilize. Much that has been said about parental care in dinosaurs is supposition: did the duck-billed dinosaur *Maiasaura* bring food to the young (Horner and Gorman, 1988) as has so often been portrayed? Maybe. But without a time machine to go back and *see* that behavior, we will never know. Much of the work on parental care in dinosaurs is based on joint development in the young (Horner and Dobb,

1997). The argument is that if the knee joint is poorly developed in the babies, then the babies must have been nest-bound and the parent must have brought them food. But anyone eating a chicken leg knows that there is a thick cartilage cap on the ends of the thigh (femur) and drumstick (tibia). Chicken we buy to eat are young (and tasty), so the knee joint is not very well developed, yet chicks are active as soon as they hatch. Clearly then, we cannot draw too much from poorly developed knees in baby dinosaurs.

So does that mean that there was *no* parental care in dinosaurs? Actually, we know that *Oviraptor* sat among its eggs (Figure 3; Novachek, 1996) because about a dozen specimens are now known associated with

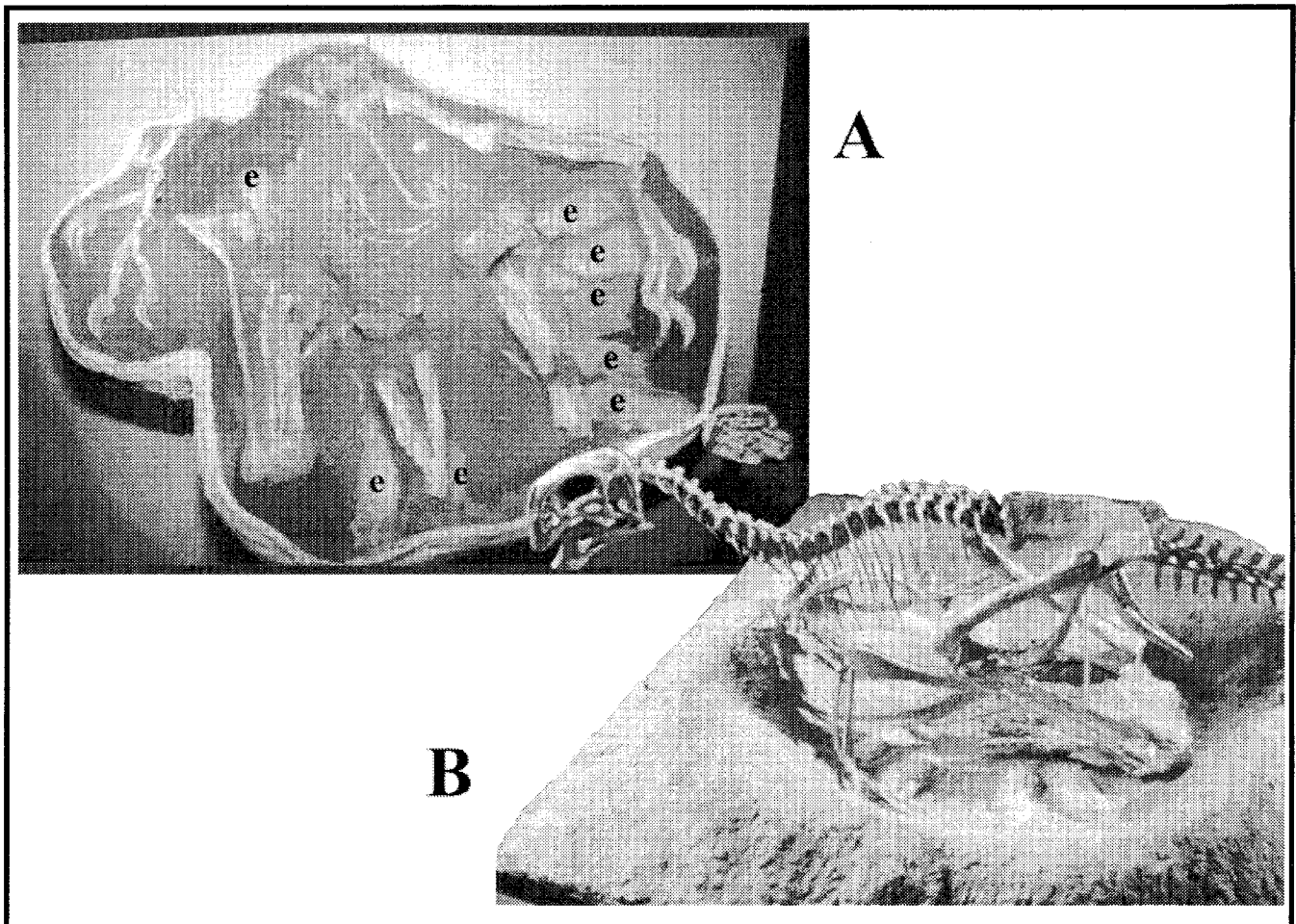
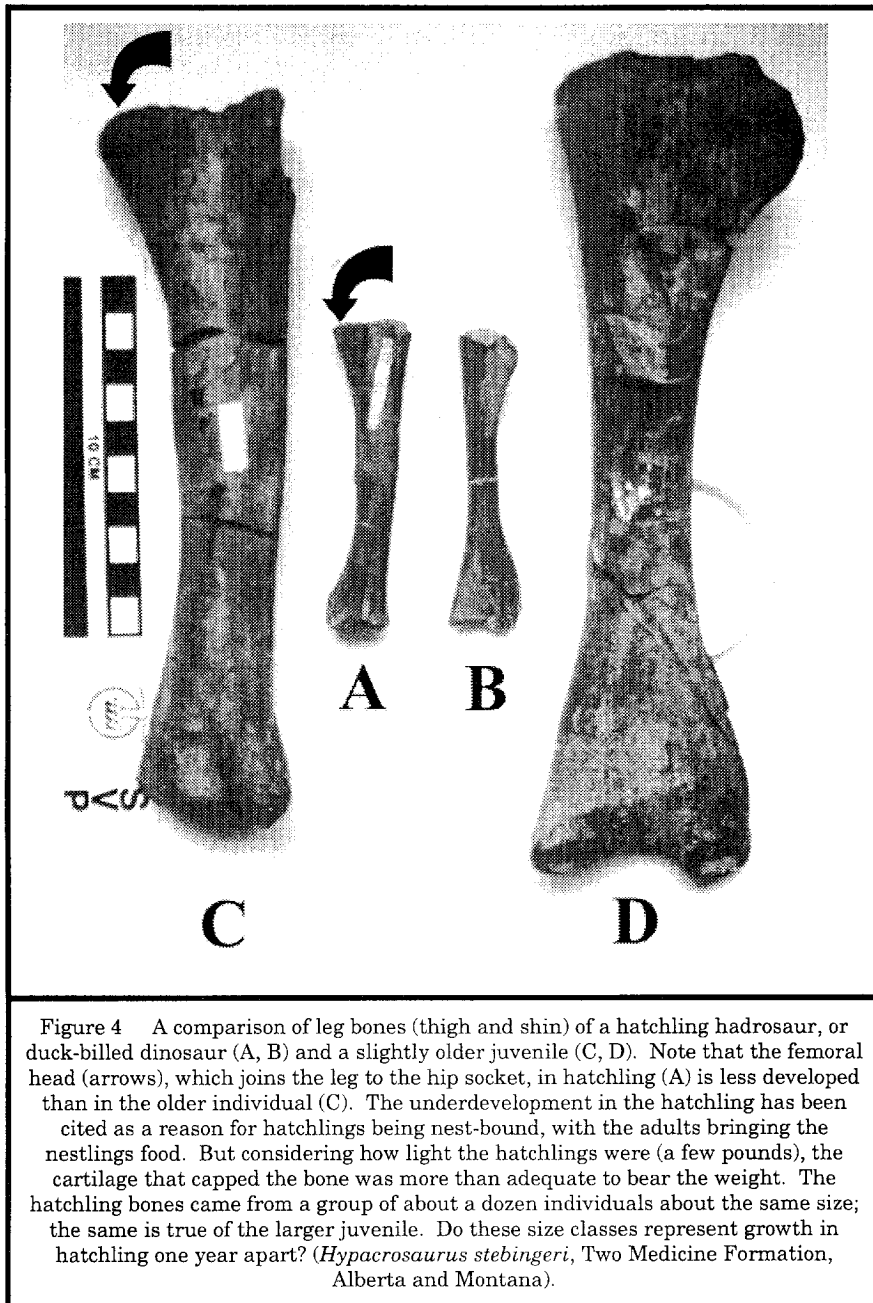


Figure 3 Parental care of eggs is best illustrated by specimens of *Oviraptor* sitting in a ring, or clutch of eggs. A, This adult specimen is lying with its legs folded under the body and the arms out stretched over some of the eggs (e). Unfortunately, erosion destroyed the upper portions of the body. B shows a reconstruction of A using a cast skeleton of the crestless oviraptor *Ingenia*. Although a rimmed edge nest is reconstructed in B, there no evidence for this is A. It is just as likely that the eggs were laid directly on the ground ostrich-style. (A at the American Museum of Natural History; B courtesy of Charles McGovern).



eggs. What we don't know yet is whether the adult skeletons are all females or males. Although the tendency is to assume that the guardian is female, it is important to remember that both males and females among many birds tend the eggs. As yet, no analysis has been done of the oviraptors to determine the gender of the guardians. We also do not know if the guardian was brooding the eggs in bird-fashion or protecting them. Brooding involves direct transfer of body heat from the parent during incubation. Because

not all the eggs in the *Oviraptor* clutches are in contact with the body (when the body of the parent is restored), brooding may not have occurred. If not, then the parent may have been guarding the eggs. As for other dinosaurs, the fossil record doesn't provide evidence about guarding or brooding of the eggs.

What about after the eggs hatched? What parent care was there? The best evidence is based on trackways of dinosaurs. On a beach, if you find very large human footprints

and very small prints side-by-side and trending in the same direction, you would probably conclude a child walking with an adult. Furthermore, footprints cannot be moved to another area; they occur where they are formed and they record everyone who was there during that interval. So it is with dinosaur footprints: they record everyone who was there and show who was traveling together. It is reasonable to assume that similar shaped footprints close together and trending in the same direction are individuals of the same species traveling in a herd. For such trackways, assuming that the large prints are of adults, then the smallest prints (hence youngest individuals) are about half the size. Very small tracks of babies do not occur with adult-sized prints, but are found elsewhere.

From this evidence, we can conclude that baby dinosaurs were segregated from the adults until they were about half grown. By that size, the smaller dinosaurs could keep up with the adults (anyone who has watched an adult strolling through the mall with a 3 year-old in tow can see the importance of size: the poor kid is jogging to keep up!). From the footprint evidence of dinosaurs, we would expect that fossil deposits where many individuals of a single species were buried together, would only contain animals less than half size or else would contain a mixture of both half-grown and larger individuals. Indeed, that is just what is known. It would appear that baby dinosaurs of some species stayed together as a creche (herd?) until they were half grown and could join the herd. Such a life style would mean that the babies were on their own - no parental care (Carpenter, 1999).

If baby dinosaurs were segregated from the herd until they were half grown, how long did that take from hatching? Not surprisingly, we really don't know. Speculations on growth rate range from very rapid bird-like rates of growth (Horner and Dobb, 1997) to very slow reptile rates, and even rates in between. The bird-like rates of growth mean that the hatchling would double its size in a matter of weeks or months, whereas the reptilian rates of growth would mean that it would take months or

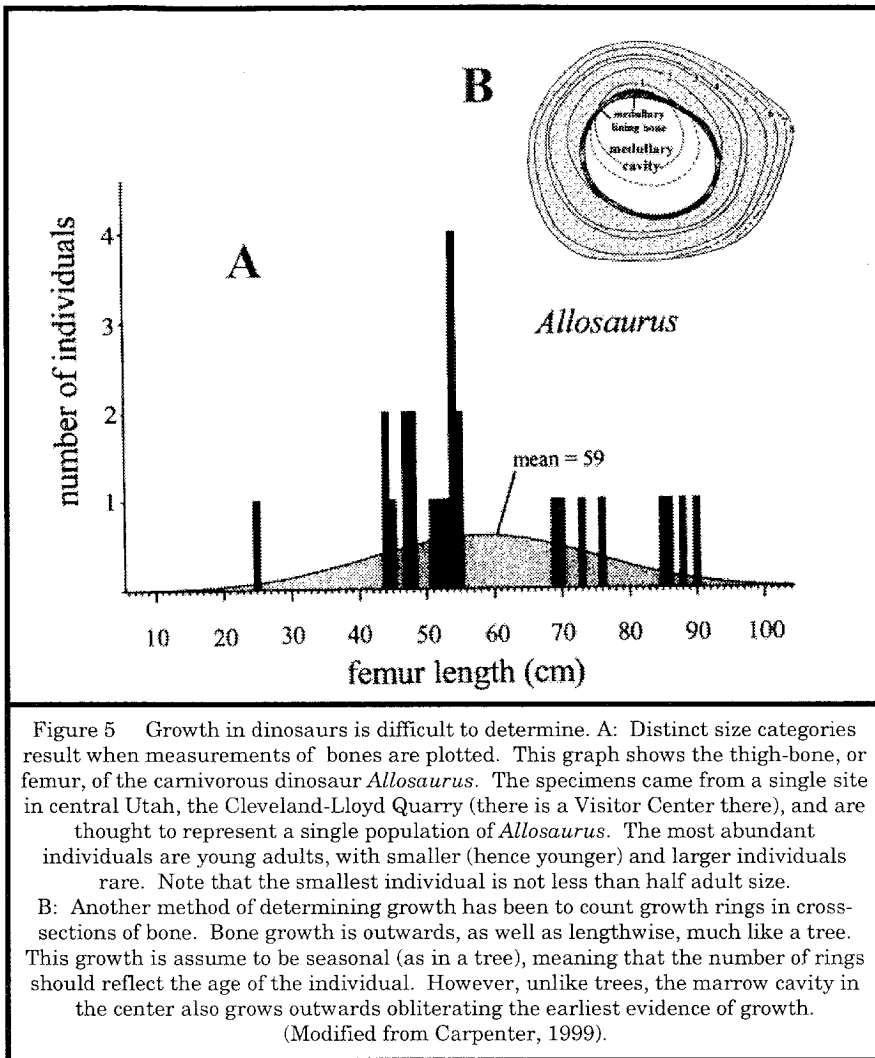


Figure 5 Growth in dinosaurs is difficult to determine. A: Distinct size categories result when measurements of bones are plotted. This graph shows the thigh-bone, or femur, of the carnivorous dinosaur *Allosaurus*. The specimens came from a single site in central Utah, the Cleveland-Lloyd Quarry (there is a Visitor Center there), and are thought to represent a single population of *Allosaurus*. The most abundant individuals are young adults, with smaller (hence younger) and larger individuals rare. Note that the smallest individual is not less than half adult size. B: Another method of determining growth has been to count growth rings in cross-sections of bone. Bone growth is outwards, as well as lengthwise, much like a tree. This growth is assumed to be seasonal (as in a tree), meaning that the number of rings should reflect the age of the individual. However, unlike trees, the marrow cavity in the center also grows outwards obliterating the earliest evidence of growth. (Modified from Carpenter, 1999).

years (Figure 4). Several different approaches have been taken to revolve this issue of growth. One method is to place easily measured bones (such as the thigh bone, or femur) into size categories (Figure 5A). Distinct groups result, not a continuum as you might expect. Do these size groups represent individuals that hatched during the same season? If so, then the doubling of size at yearly intervals mean growth slower than in birds, yet faster than reptilian rates. Some supporting evidence for this interpretation comes from within the bone. In juvenile bone, there are numerous bone cells implying rapidly growing bone, but these decrease in older individuals. From this, we can interpret very rapid growth in baby and juvenile dinosaurs, but slowed growth as the individuals approach adulthood. Growth in many dinosaurs is assumed

to have been seasonal, with more growth when food was most abundant, presumably summer. These spurts in growth result in bone being formed episodically, producing rings much like a tree (Figure 5B). Again,

this evidence would seem to indicate growth was faster than in reptiles, but slower than birds. We are assuming, however, that the growth rings in bone represent yearly increments, but there is no proof (e.g., if there were two rainy seasons in a year, then conceivably there could be two spurts of growth per year in herbivorous dinosaurs). Further complicating the story are that not all dinosaur bone shows growth rings.

One important aspect of dinosaur growth that we have not covered, is how do we know that a small individual represents a juvenile, rather than a small adult? Actually, there was a time when many immature dinosaurs were thought to be distinct species, and so named. However, using comparative anatomy, the juvenile characters become obvious. For example, the study of joint development in modern birds and reptiles shows that joints slowly change as the individuals age. In the very young, the joints are under developed and are mostly cartilaginous. But as growth slows in the adult, the joints become more boney. In very old individuals, the joints may become knobby with excess bone deposits. The same stages may be seen in dinosaurs (Figure 4). Also, as with most baby animals, baby dinosaurs are characterized by large heads compared to body size, and very large eye sockets (Figure 6). In rare instances, a growth series is available that allow us to see the changes as certain structures develop (Figure 7).

The study of dinosaur reproduction is still an immature science (no pun intended). Although we have

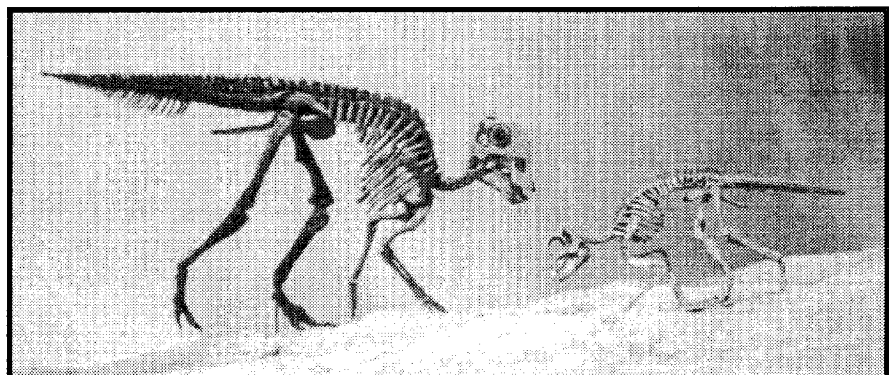


Figure 6 Baby dinosaurs are characterized by large eye sockets set in skulls that are large compared with the body. Here are two reconstructed skeletons of a hatchling hadrosaur (right) and slightly older juvenile (left).

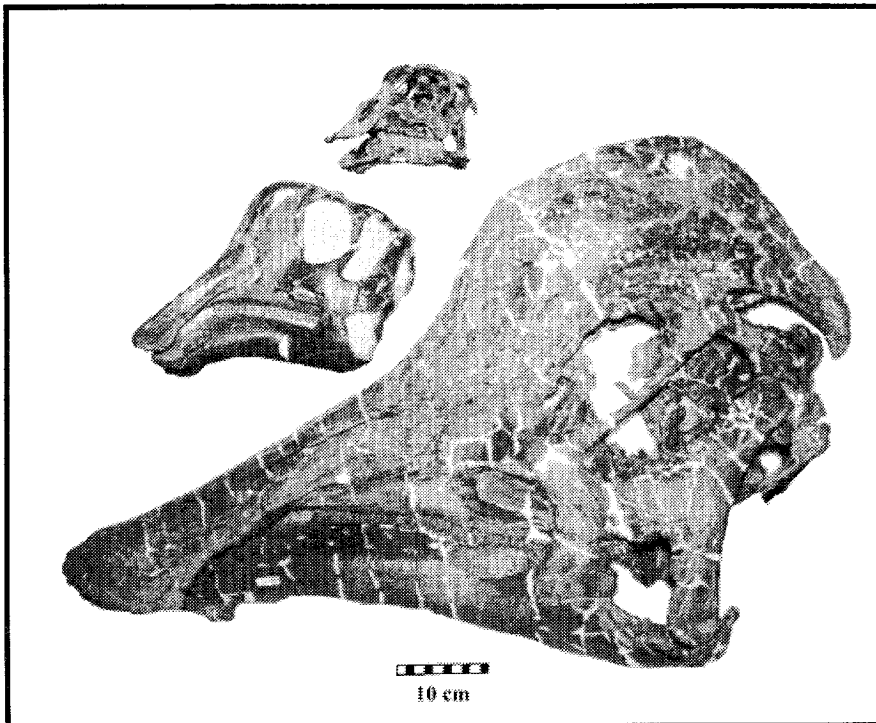


Figure 7 Changes in the skull of the hadrosaur *Hypacrosaurus* is seen in development of the crest.

In the smallest skull, there is a slight doming of the forehead. This doming becomes more pronounced as the individual ages, until a crest is fully formed in the adult.

Mapping the changes in structures like this is only possible when a growth series is available. These growth series have been important in the recognition that an earlier named dinosaur was actually the juvenile form of another.

In this example, the intermediate-sized skull was named *Procheneosaurus praeceps* in 1920, but this growth series demonstrated that the skull is actually a juvenile *Hypacrosaurus stebingeri*.

begun to understand something about mating, egg laying and growth, there is still much that we do not know. We assume that all dinosaurs laid eggs because eggs with embryos are known for most of the major dinosaur groups. The microscopic structure of small carnivorous dinosaur eggs is nearly identical to modern bird eggs, supporting the bird-dinosaur link. But whether any of these dinosaurs weaved elaborate nest like some modern birds, we do not know. Further study and new specimens will undoubtedly reveal much more about dinosaur reproduction in the next few years.

Literature Cited

A lot of work on dinosaur eggs and baby dinosaurs is in the scientific literature and is often difficult to obtain. I have, therefore, tried to cite

popular literature that is not difficult to locate).

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