h14 Saurischia < carnivorous and herbivorous types, triradiate pelvic girdle >

> Dinosaurs were named in 1841. Before then in Massachusetts, first finds in 1802 had been three-toed tracks (of Jurassic theropods) dubbed the "the trail of Noah's raven," and enigmatic, larger, four-toed tracks (of Triassic prosauropods).[1]

Dinosaurs are a group of ruling reptiles that became extinct at the end of the Mesozoic. The group is paraphyletic, as birds, which are derived from a dinosaur ancestor, are *not* included. Those which retained a reptilian arrangement of hip bones are the order Saurischia (***Figure h14.1***). As such, they could be polyphyletic (several ancestral lines) and so Saurischia may not be a natural order.

Order Saurischia (***Table h14.1***) is divided into a carnivorous suborder Theropoda (devil's feet) that leave a bipedal, three toed, birdlike track and a herbivorous suborder Sauropodomorpha (reptile-footed forms) that, because they tend to gigantism, are quadrupedal.[2] Of the theropods (three-toed foot), the most advanced tetanurans (three-fingered hand) were the coelurosaurs which includes families Dromaeosaura, Oviraptora, and Ornithomimida. These were small, slender limbed, lightly built, fast-running reptiles that, in Bernhard Kummel's words, "must surely have caused the smaller [herbivorous, and the young of all] dinosaurs plenty of trouble." [3] Some could swim.[4] Some, once thought to have been egg stealers, have been vindicated but there is no reason that others were not.

Table ***h14.1*** [5] **Classification of saurischian dinosaurs**

ORDER		SUBORDER		INFRAORDER	GENUS
Saurischia  (Reptilian arrangement of the hip bones with an acetabulum.)	 (A variety of stocks but all stem from an ancestor with hands that enabled some grasping ability.)	**Therapoda**  (Three-toed foot.)	**Tetanurae**  (Three-fingered hand.)	**Coelurosaura** (Relatively long arms.)	
				F. Dromaeosaura	*Velociraptor* *Deinonychus*
				F. Oviraptora	*Oviraptor*
				F. Ornithomimida	*Ornithomimus*
				Carnosaura	*Tyrannosaurus* *Allosaurus*
				Ceratosaura	*Dilophosaurus* *Coelophysus*
		Sauropodomorphia (quadrupedal, reptile-footed forms.)		**Sauropoda**	*Alamosaurus* *Seismosaurus* *Apatosaurus*

Primitive saurischians were relatively small (1 to 2 meters in adult length), bipedal, hollow vertebrae and limb bones, long hind legs, short forelimbs, clawed toes and fingers, and lining the length of the jaw, had numerous sharp teeth well adapted for eating meat.

Coelophysus, one of the oldest known dinosaurs, is typical of the Late Triassic primitive saurischian genera.

Of dinosaur carnivores stalking a large herbivore, trackways have all been of a lone putative stalker.[6] So fossils of several small theropods together with a possible victim, is not prima facie evidence for small carnivorous dinosaurs hunting in packs with, say, the communal cohesion of hyenas that band together to bring down a wildebeest, or orcas that individually hunt seals but cluster to separate a great whale from a pod and then tear it apart. To a news-article headlined "Dinosaur, partly of six, meat eating," which was unreflective on this point, querulous Ross Agreen wrote: "Vultures mass at a carcass, but would you say they are pack hunters?" So too a murder of crows.

Dromaeosaurs

A bird wakened in the lunar moon / Sang halfway through its little inborn tune.
—Robert Frost (1874-1963), "On a Bird Singing in Its Sleep."[7]

Clear evidence that some of the dinosaurs were very agile, are Late Cretaceous *Velociraptor* (adult length 2.5 meters) and *Bambiraptor feinbergi* (Montana, juvenile length 0.7 meters, weight 2 kilograms), and Early Cretaceous *Deinonychus* (adult length 1.8 meters, weight 45 kilograms). Characteristic of dromaeosaurs is a large sickle claw on each hindfoot designed to strike and slash at prey. Also present were ossified tendon reinforcements in the tail to anchor balancing muscles used when leaping and turning. Birds (*see* Topic *h17*) could have diverged from dromaeosaurian stock (which were feathered and of which *Cryotovolans* had flight-adapted feathers and *Velociraptor* and *Deinonychus* could have been secondarily flightless).[8] For flight, evolution had been to small size.

Oviraptors (egg stealers)

> Monitors that [today] feed on the eggs of other reptiles can locate a clutch buried in sloping, backfilled tunnels. They do not gain access via the tunnel entrance, which is often three feet or more away from the eggs; instead, they dig straight down from above.
> —Samuel S. Sweet and Eric R. Pianka, *The Lizard Kings*, 2003.[9]

Found during a 1994 American Museum of Natural History expedition to the Gobi Desert was the fossil of a 2.5 meter long, carnivorous, long-armed, bipedal, coelurosaur upon a nest of dinosaur eggs. Overwhelmed by a large dust storm, this dinosaur had been buried in place 80 million years ago. Of the type-genus *Oviraptor,* its long and slender forelimbs were with three long, clawed, fingers suited to grasping, ripping, and tearing. Its short skull was with very large eyes (possibly capable of stereoscopic vision) each set in a bony ring. Its jaws lacked teeth but their bone was likely sheathed by a beaklike corneous covering. In this fossil, the legs are folded beneath the body and the forelimbs surround a clutch of some 15 eggs arranged in a circle. **Xu Xing** [10] and Mark Norell see its posture as indicative of incubation and reason this oviraptor, contrary to its name, was on its nest to protect it from predators, to shade it, and to shelter it from (what else?) dust storms.[11]

Ornithomimids (bird-mimics) [12]

Living herbivorous birds have a gizzard (a muscular ventricular stomach) with grit to grind up plant matter. In this, they are convergent in evolution with extinct ornithomimid (non-avian, toothless) theropods in which herbivory may have evolved on several occasions. (Insectivorous or omnivorous birds have less grit in their gizzard and frugivorous birds have almost none. Carnivorous birds have no muscular gizzard.) The Late Cretaceous genus *Ornithomimus* (3.5 meters long) had slender, muscular legs adapted for running, toothless beaklike jaws, and a thin-boned skull with a large brain cavity in its small head. These "ostrich-like" dinosaurs were un-ostrich-like in their long, balance enhancing, outstretched tail, long arms and hands with three-fingers, and sharp claws, adapted for grasping (but what?). Speculation has been that the gracile Late Cretaceous genera *Struthiomimus* (2.5 meters long) and *Gallimimus* (3.5 meters long) with very birdlike legs with three toed feet, but with long arms and reaching hands, fed upon the eggs of other dinosaurs. However, twelve well-articulated ornithomimid dinosaur skeletons, collected in 1997 from the Late Cretaceous Ulansuhai Formation, China, were with gastroliths (located where the gizzard would have been) of amount, size distribution, and composition (silicate, with no bony elements or insect remains) that spell herbivory. Yoshitsugu Kobayashi and others who have described these fossils point out that "the fully terrestrial

habitat of this ornithomimid rules out the possibility that the gastroliths were used for hydrostatic adjustment, as has previously been recorded for plesiosaurs, crocodilians and a tanga-saurid. The small calcium content of the grains indicates that they were unlikely to have been used for the uptake of calcium nutrient, as in birds." Gastroliths, although patchily distributed in dinosaurs, are most often associated with herbivorous (ceratopsian *Psittacosaurus mongoliensis* and sauropods) or putatively herbivorous (oviraptor *Caudipteryx zhoui*) groups.[13] An edentulous (toothless) beak is preserved as a keratinous rhamphotheca (corneous sheath) over the tips of the right premaxilla and dentary bones (the bill) in the almost complete skeleton of the Campanian ornithomimid *Ornithomimus edmontonicus* from Dinosaur Provincial Park, Alberta, Canada, and also in a sub-adult of *Gallimimus bullatus* (a 70 million year old fossil) from Tsaagan Khushu, Nemegt Basin, Gobi Desert, Mongolia. Described in 2001 by Mark A Norell, these likely fed as do (most) anseriforms (order of birds that includes ducks, geese, and swans), by manipulating food and by straining sediment with their beaks. Corroboration that ornithomimids were *not* ostrich-like in their diet are comblike plates (remnants of which are individual strands of material about 5.6 millimeters long and seated about 0.5 mm apart) inside *G. bullatus* upper and lower jaw beaks. *G. bullatus* was the largest ever (2.1 meter tall ones weighing in at 320 kilograms) land filter feeder (gleaning plant and small crustaceans from water and mud in the manner of ducks).[14]

Late Cretaceous beaked ornithomimids were derived from earlier Cretaceous ones that had teeth. That once feature places all the originally, and still often called "ostrich dinosaurs" (a nomen dubium in that no clear taxonomic group is described), in the clade "carnivorous theropods."

Carnosaurs and **Ceratosaurs** [15]

Tyrannosaurus, the largest *terrestrial* flesh-eater ever (length 12.4 meters, height 4.6 to 6 meters, weight 5 to 7 tons) was accompanied during the Cretaceous by smaller, similarly two-fingered, tyrannosaurids: *Albertosaurus*—first found (inadvertently) by Joseph Burr Tyrrell (1858-1957) in 1884,[16] *Daspletosaurus, Tarbosaurus*, and *Carcharodontosaurus*. These succeeded and, likely, occupied the same ecological niche as had the three-fingered carnosaurs: *Acrocanthosaurus* (Early Cretaceous) and *Allosaurus* (Late Jurassic) in the evolutionary relay from ceratosaur *Ceratosaurus* and waddling carnivorous megalosaurs. All were strictly bipedal as their relatively puny arms (3 feet long in *T. rex*) could in no way have supported their great weight. Their huge heads (5 feet long in *T. rex*) bore massively muscled jaws lined by sharp bladelike teeth.

Sauropods and **Prosauropods** [17]

Sauropods, were the largest *terrestrial* plant-eaters ever (length 21 to 27 meters, height 4.6 meters at the hips, weight 33 to 38 tons and, scaling greater in all these measures, to giants of giants—the titanosaurs—weighing more than 80 tons). (For comparison, an African elephant, which is the largest living land animal, weighs up to 8 tons.) The first evidence of Sauropoda (Marsh, 1878 sensu Wilson & Sereno "lizard feet") was in 1849 when from Wealden strata, England, a miller at Malling Hill, near Lewes, retrieved what Gideon Mantell called "a glorious specimen of a humerus." This at four and a half feet long was a portion of the greatest arm bone yet then known. Mantell first tried "*Colossosaurus*" as the name for it and then, in 1849, he proposed "*Pelorosaurus*"(Gk. *pelor* means monster) when (as a rebuke to Owen who had unfairly belittled his contributions) he could also reclassify from the same pit *Cetiosaurus* (a huge lumbar vertebrae which Owen had named and misidentified as of a type of crocodile) as of a second new colossus that Mantell discovered in Isle of Wight specimens were with the requisite fused sacrum of the "dinosaurian type." [18]

The last sauropods, and present to the ill-fated end of dinosaur's existence, were the titanosaurs (almost three dozen types have been described). Their fossils have been found on every continent except Antarctica. Most are very incomplete body parts and only in the late 1990s has a skull been excavated that matches the titanosaurs' body. This is of a 70-million-year-old Madagascan titanosaur species, an adult that would have been about 12 meters long, named *Rapetosaurus krausei* by K. Curry Rogers. Titanosaurs appeared 100 million years ago (Late Cretaceous) when dying out were other sauropod dinosaurs such as *Alamosaurus* of North America and *Laplatasaurus* of South America.[19] The greatest diversity and abundance of these had been in Laurasia and Gondwanaland during the Late Jurassic. Then also roamed sauropod "brontosaurs," beloved by generations of

children possibly for the ease by which it can be recognizably drawn (pointed long tail that thickens to a barrel body on stumpy legs; a long snakelike neck and a knob of a head) and by virtue of its being the first (identifiable) animated cartoon character *Gertie the Dinosaur* introduced in 1914 to cinema audiences in Chicago by Winsor McCay (1875-1941).[20] The sauropod limb bones, adapted to bearing great weight, were solid and thick. The feet were broad, close to plantigrade, and five toed. A large straight claw on the first digit of the forefoot and the first and second toes of the hindfoot, present in some, could have aided traction. (Elephants today, without such on their feet, use a tusk to lever their climb up a steep, sandy, river bank.) The most surprising aspect of Sauropods, as giant herbivores, was their disproportionately small heads and seemingly unsuitable teeth. Their heads came in two styles: *Camarasaurus*' high, broad, boxy head and spatulate teeth; and, *Diplodocus*' low, narrow, streamlined head and pencil-shaped teeth. The genus name *Brontosaurus* ("thunder lizard") was discontinued and replaced in 1903 by *Apatosaurus* ("deceptive lizard") after John Stanton ("Jack") McIntosh saw that in piecing together a type body for museum display, a camarasaurus-type head had been erroneously attached whereas a diplodocus-type is correct.[21] Late Jurassic diversity included *Diplodocus* (the first US exhibited dinosaur—minus its head), *Seismosaurus, Brachiosaurus*, and smaller kinds like *Barapasaurus*.[22]

Brachiosaurs were unique in having very much longer forelegs legs than hindlegs. This is an usual condition for four footed animals. (Even giraffes, which bear a passing likeness to these extinct beasts, have forelegs no longer than their hindlegs. A great mass of muscle atop their shoulders that supports their neck accounts for the sloping giraffe back and the illusion that fooled Lamarck! of longer forelegs. The giraffe has a short body compared to its long legs and neck that raise its head to a height of 5.5 meters and make it the tallest of all living mammals.) Brachiosaurs attained a length of at least 23 meters, weighed 80 metric tons. They had a deep, domed head that terminated in a broad, flat snout. *B. brancai* mounted in 1937 in the Museum für Naturkunde, Berlin, is world's tallest.[23] With forefeet on the ground, it could raise its head to a height of 12 meters. The inference from giraffes' acacia-tree browsing is that brachiosaur adaptations were for browsing so but Mesozoic conifer stands were of trees 40 meters tall with only the upper-quarter branched and bearing leaves and cones.[24] Like elephants they may, for themselves and their young, have pushed over tall trees to browse, but with forefeet rather than the head. Early visions of these great beasts partly submerged and feeding in water have been discounted mainly because water pressure at the depths pictured would have prevented breathing by compressing their throat closed. Also, the snorkel position of the nostril was discounted in 2001 by Lawrence M. Witmer: the animal would have no need of it in shallow water out of which it could stick its head, and in deeper water, what use?[25] *Diplodocus* would not have been able to breach for a blow and a breath like a dolphin or a whale. Witmer finds some evidence in blood vessel and cartilage impressions in head bones of the long necked dinosaurs to position a fleshy nasal-passage opening near the snout (as is so in crocodiles and lizards).[26]

The tracks of sauropods show that they lived and herded as do elephants today. Their quadrupedal gait Robert R. Reisz notes "may have evolved through paedomorphosis (the retention of early ontogenetic features in the adult) as first suggested by Bonaparte and Vince."[27] No tail drag marks or stepped on crushed tail bones indicate that a sauropod carried its tail, for all its length and whip-cracking end, clear of the ground. The Paluxy River, Texas, dinosaur trackway authenticated by Roland Thaxter Bird (1899-1978) in 1938 [28] and since dated at 100 million years old, has been analyzed to show that a quadruped sauropod (possibly an *Acrocanthosaurus*) had, atypical for a reptile, an elephantine gait wherein both feet on one side of the body are raised simultaneously in brisk walking. This allows the hindfoot to step where the forefoot was. At Purgatoire, south of La Junta, Colorado, 150 million years ago they peed 1,300 liter volumes at a go as they went.[29]

Did sauropods hatch from eggs? From what height would the egg be dropped? Could the clumsy mother avoid trampling the eggs? More reasonably, therefore: Were they born alive? In 1997, answers came from the finding in the Auca Mahuevo site, Patagonia, of several stratigraphic flood-plane layers with thousands of six-inch in diameter spherical eggs, in clusters of 15-30, and these only two to ten feet apart. Not to trample the mother *must* have left, but did the parent(s) patrol the periphery of the laying area to ward off predators? Lowell Dingus writes: "Within some of the eggs, we found fossilized embryos, the first embryos [and skin casts] of a sauropod ever uncovered. The skulls, large in relation to the bodies [as so of most animals as eyes are near full size before birth] are each about an inch long. The skulls have a bony structure like that found in a group of South

American sauropods called *titanosaurs*. This identification is strengthened by the embryos' minute teeth, less than one-sixteenth of an inch long, which are also like those of titanosaurs."[30]

Late Triassic sauropods of Pangea ranged in adult size from *Riojasaurus*, 7 meters in length, to *Vulcanodon*, 30 meters in length. Also *Isanosaurus attavipachi* found in Late Triassic sediments of Northeastern Thailand and *Deuterosauropodopus* footprints in Losotho (both sites then of Pangea) is evidence of a vast geographical distribution of sauropods.[31] They were already a separate lineage to a sister-group of prosauropods. For example, a sauropods predecessor is *Antetonitrus ingenipes* ("before the thunder" and "massive paw") which Adam Yates described in 2001. Its bones were collected from Late Triassic sediments of the Karroo region of South Africa[32] by James Kitching in 1981.[33] *Antetonitrus* has nearly equal-length legs which indicate that it walked solely on four feet (a sauropod trait). This and other skeletal traits such as giant size compared to its contemporaries suggest to Yates that it was a strict herbivore. A primitive character is a flexible, clawed thumb possibly used for gripping or defense against predators (a prosauropod trait). A contemporary of *Antetonitrus*, Late Triassic *Plateosaurus* is judged to be more primitive because of its feet and hands are closer to the bipedal condition that all ancestral dinosaurs as evolved archosaurs are presumed to have had. Otherwise *Plateosaurus* is closer in its aspect to the sauropods than any other dinosaur alive then or known to have been living before. As such, *Plateosaurus* (suborder Sauropoda, infraorder Prosauropoda), ubiquitous in Pangea, was a living fossil of its day.

Adult prosauropods had forelegs shorter than their hindlegs, and being much smaller than sauropods were at least facultatively bipedal, and being closer to carnivore roots, speculation is that they were occasional meat-eaters. Their hatchlings, however, in the known case of *Massospondylus carinatus*, were obligate quadrupeds.[26] ❑

Figure h14.1 **The phylogenetic tree of the saurischian dinosaurs**