PART FIVE

EPILOGUE

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Skeletal Reconstruction of *Brachiosaurus brancai* in the Museum für Naturkunde, Berlin: Summarizing 70 Years of Sauropod Research

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THE SKELETAL RECONSTRUCTION OF *Brachiosaurus brancai* displayed in the Museum für Naturkunde, Berlin, is the largest mounted dinosaur skeleton in the world that incorporates original fossil material. Found during the course of the German Tendaguru expedition from 1909 to 1913, a composite skeleton of *B. brancai* was first mounted in 1938, and although it was demounted and remounted several times, it remained unchanged until the renovation of the Berlin dinosaur exhibition hall in 2005–2007. Here we describe the scientific progress, technical solutions, and specific decisions that led to the new mount, which has been on display since 2007. The new mount differs in a number of points from the old mount, including improved models of the presacral vertebrae and head, the posture of the neck, the shape of the torso, the orientation of the pectoral girdle and forelimbs, and the posture of the tail. Overall, the *Brachiosaurus* skeleton now looks livelier, evoking the impression of an active, relatively agile animal and symbolizing developments in our understanding of sauropods since the first mounting of the skeleton.

Introduction

In July 2007, the famous Dinosaur Hall of the Museum für Naturkunde in Berlin reopened after two years of reconstruction and renovation, returning one of the world's most famous dinosaur mounts to public view. The original reconstruction of *Brachiosaurus brancai* by Werner Janensch (1937; Fig. 18.1) has been emblematic of sauropod gigantism since the late 1930s, and pictures of the Berlin *Brachiosaurus* can be found in countless textbooks, popular articles, children's books, and posters around the world. However, research on sauropod dinosaurs has made substantial progress since Janensch's time, and the complete renovation of parts of the Museum für Naturkunde's exhibitions, which began in 2004, provided a unique opportunity to update the Berlin reconstruction according to our current understanding of sauropod paleontology. Discoveries made by the DFG Research Unit 533, as described elsewhere in this volume, had a substantial influence on the new *Brachiosaurus* mount, but would not have been possible without the tremendous research efforts of Richard McNeill Alexander, Robert Bakker, Paul Barrett, José Bonaparte, Eric Buffetaut, Jorge Calvo, Matt Carrano, Per Christiansen, Peter Dodson, John Foster, John Hutchinson, Martin Lockley, John McIntosh, Leonardo Salgado, Paul Sereno, Paul Upchurch, Mark Wedel, Jeff Wilson, C. C. Young, Dong Zhiming, and many others. Debates on sauropod anatomy, posture, and paleobiology continue today, and not every sauropod researcher will agree with all aspects of the new reconstruction now on display. Therefore, as an epilogue to the issues discussed earlier in this book, we describe the history and science that led to the new *Brachiosaurus* mount on show in Berlin, and how the results of studies by our research group influenced individual decisions.

FIGURE 18.1. Original mount of *Brachiosaurus brancai* in the Museum für Naturkunde, Berlin in 1938. Note the elbow-out position of the forelimbs, the bent knees, and the tail dragging on the ground.

History and Components of the Mount

All the original dinosaur specimens in the dinosaur hall of the Museum für Naturkunde, Berlin, were discovered in the Late Jurassic (Kimmeridgian–Tithonian) Tendaguru Beds of southern Tanzania, East Africa. From 1909 to 1913, Werner Janensch led one of the most productive paleontological excavation campaigns in history to the area around Tendaguru Hill, about 60 km northwest of the port town of Lindi (Janensch 1914; Maier 2003). More than 250 metric tons of fossils were transported back to Berlin, including two partial skeletons from Tendaguru site "S" that form the main part of the *Brachiosaurus* mount today (Janensch 1937). After World War I, preparation proceeded slowly, and it was only in November 1937 that the reconstruction of *Brachiosaurus* was opened to the public (Janensch 1937, 1950; Fig. 18.1).

The mount of *Brachiosaurus brancai* is a composite because no complete skeleton was found by the German Tendaguru expedition of 1909–1913 (Janensch 1950). Janensch (1950) described in detail the source of the individual bones and the rationale behind his mount. We repeat here the complete information on the provenance of the bones to make it accessible to a wider audience. The majority of the skeletal elements included in the mount are from skeleton S II, recovered from the Middle Saurian Beds (Tendaguru site "S"). The tail skeleton is derived from another individual of similar size found in the Upper Saurian Beds at Tendaguru site "no." In addition, skeletal elements of comparable dimensions to S II, obtained from different sites in the Tendaguru area, were also included in the original mounting, both as originals and as reconstructions.

The skull of the original mount was modeled in plaster on the basis of skull fragments, including lower and upper jaws from skeleton S II. Missing parts were reproduced from the remarkably well preserved complete skull t 1. Skeleton S II provided the presacral vertebral column, including 11 cervical and 11 dorsal vertebrae, but because of their extreme fragility, only plaster copies were incorporated into the mount. The sacrum was completely modeled in plaster on the basis of two specimens found at Tendaguru sites "Aa" and "T." Skeleton "no" supplied a series of 50 articulated caudal vertebrae for the tail, at the tip of which four small pieces were added as freehand reconstructions in plaster. The missing first caudal vertebra and most of the chevrons were also modeled in plaster. Cervical ribs were reconstructed in plaster on the basis of incomplete examples from skeleton S II. With the exception of four plaster reconstructions, the dorsal ribs are originals from skeleton S II.

The right scapula is a plaster reconstruction that used the original left scapula as a guide. The right coracoid and forelimb, with the exception of a carpal bone in plaster, consists of originals from S II; also originals are the left scapula, the coracoids, sternal plates, and the left humerus, radius, and ulna. The left manus was constructed entirely from plaster using the original manus from the opposite site as a guide.

The right ilium is an original from Tendaguru site "Ma," while the left ilium is a reconstruction in plaster mirrored from the right ilium. Both pubes are S II originals. The right ischium came from Tendaguru locality "L," and the left ischium was modeled in plaster as a mirror image of the latter. The hindlimbs are composites of bones of S II and other skeletons, partly original and partly modeled in plaster. The left femur is a fragmentary S II original completed with plaster, and the right femur an original from Tendaguru site "Ni." The right tibia and fibula are S II originals, whereas those from the left side are derived from Tendaguru site "Bo." The ankle bones are plaster imitations modeled from skeleton "Bo" originals, while the remaining elements of the hind feet are composites, mainly modeled in plaster, of badly preserved foot bones from skeleton S II and other finds.

Preliminary work on the mount commenced under Janensch in 1934 (Maier 2003) and took advantage of experience gained from mounting skeletal reconstructions of *Kentrosaurus aethiopicus* (1924), *Elaphrosaurus bambergi* (1926), and *Dicraeosaurus hansemanni* (1930/1931), all of which were also from Tendaguru. Unfortunately, no sketches of the mounting of *Brachiosaurus brancai* are available in the archives of the Museum für Naturkunde. There is, however, an extended photographic record produced by the *New York Times* GmbH Berlin that documents the mounting in detail (Fig. 18.2).

First, a scale model of the mount, about 1 m high and 1 m long, was produced in plaster. This was followed by a full-scale mock-up (Maier 2003), which allowed precise measurements and adjustments of the skeletal elements. Next, a metal armature to hold the bones in the desired position was constructed. Holes were drilled in the heavy bones, and steel tubes of about 5 cm in diameter were inserted that attached the skeletal elements to the metal armature. Because the armature was largely hidden, the bones were rendered highly visible. Finally, the skeleton was supported by two vertical T bars that were anchored in a basal platform.

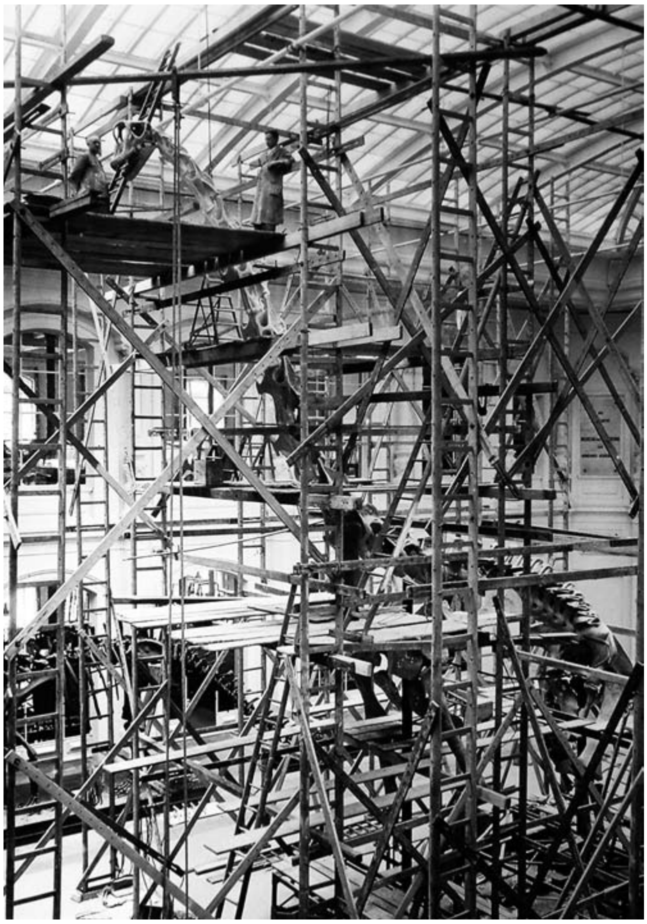

FIGURE 18.2. The mount of *Brachiosaurus brancai* shortly before completion in late 1938. The ribs had not yet been mounted at the time the picture was taken. Note the extensive wooden scaffolding and the still-uncolored plaster models of the presacral vertebrae.

The skeleton was reconstructed with a neck that sloped steeply upward, giving *Brachiosaurus brancai* a giraffe-like appearance. This clearly distinguished it from most other sauropod dinosaur mounts of the early 20th century (e.g., Hatcher 1901; Osborn & Mook 1919; Gilmore 1936). On the basis of detailed comparative anatomical examinations, Janensch reconstructed the huge forelimbs in an elbow-out position.

The mounted skeleton was of superlative size. It stood about 12 m high, was approximately 23 m long, and became the tallest dinosaur skeleton on display anywhere in the world. Overall, the resulting skeletal reconstruction was an outstanding masterpiece and a milestone in mounting huge dinosaur skeletons (Maier 2003).

During World War II, the skeleton of *Brachiosaurus brancai* was taken down for safekeeping and stored in the museum basement from 1943 onward. In the spring of 1953, the remounted skeleton was put on public view once again. It remained on display until 2005, apart from a short interval during 1984 when it was disassembled for an exhibition in Japan and then remounted in Berlin that same year.

Technical Solutions for Remounting

The dismantling and remounting of all Tendaguru skeletons in the 2005–2007 period was performed by Research Casting International, a Canadian company that specializes in conserving, casting, and mounting fossils, including large dinosaur skeletons. The dismantling of the *Brachiosaurus* skeleton was carried out during April and May 2005.

Before taking the skeleton apart, a thorough inspection of each fossil bone was conducted. This inspection determined which bones needed additional stabilization or other special attention before dismantling and ensured that each specimen was stable enough to be disarticulated and moved. All of the disarticulated skeletal sections were packed and placed in drawers or, in the case of larger elements, firmly secured to custom pallets or metal frames. Some of the smaller *Brachiosaurus* bones were removed from their armatures by hand; larger and heavier bones and sections were lowered using rigging methods. Equipment used included two articulated man lifts, scaffolding with a movable crane, and other metal working equipment including welding machines. The specimens were crated and transported in a specialized air-ride moving truck to an 800 m² storage facility about 4 km from the museum, where the preparation took place.

The original sculpted plaster vertebrae were replaced by vacuum-formed epoxy. Carbon fiber casts were taken from new molds of original bones from the museum collection. All specimens were cleaned, breaks were repaired, and all bones were stabilized before remounting. In contrast to the old mount, the internal steel tubes were not used as supportive elements. Instead, individual external steel struts and clamps were welded and shaped to fit smoothly against the surface of the bone (Fig. 18.3). Because of the organic appearance of the ultralight metal armature, this mounting method resulted in an elegant appearance that avoided damage to the specimens (e.g., by drilling through the fossils). Furthermore, all clamps can be individually removed, allowing any single bone to be separately dismounted (e.g., for scientific research) without the need for disassembling the entire skeleton.

In April 2007, the remounting of *Brachiosaurus* was begun that used the same set of scaffolding and equipment as had been employed for the dismantling.

As mentioned above, in the old *Brachiosaurus* mount, the head and presacral vertebral column were modeled in plaster, but the original elements were not suitable for reuse in the mount for a number of reasons: the vertebral laminae and individual elements of the skull are delicate and easily broken; the fossil specimens are heavy and would have required complex (and presumably unaesthetic) steelwork to support them securely; most of the original presacral vertebrae are slightly deformed and would not articulate comfortably with one another; and if mounted between 5 and 13 m above floor level, the specimens would have been out of reach for scientific examination. Therefore, in the new mount, models were used again in place of the original presacral vertebral column and head, but took advantage of modern techniques and materials. The 1937 models were rather clumsy sculptures that bore only a superficial resemblance to the original fossil material. Thus, on this occasion, we sought to produce replicas that were as similar as possible to the originals. Although the old models were made of plaster, the new models were constructed from carbon fiber. This material has many advantages: it is more lightweight than plaster, it is tougher, and complex surface structures can be more easily modeled. For

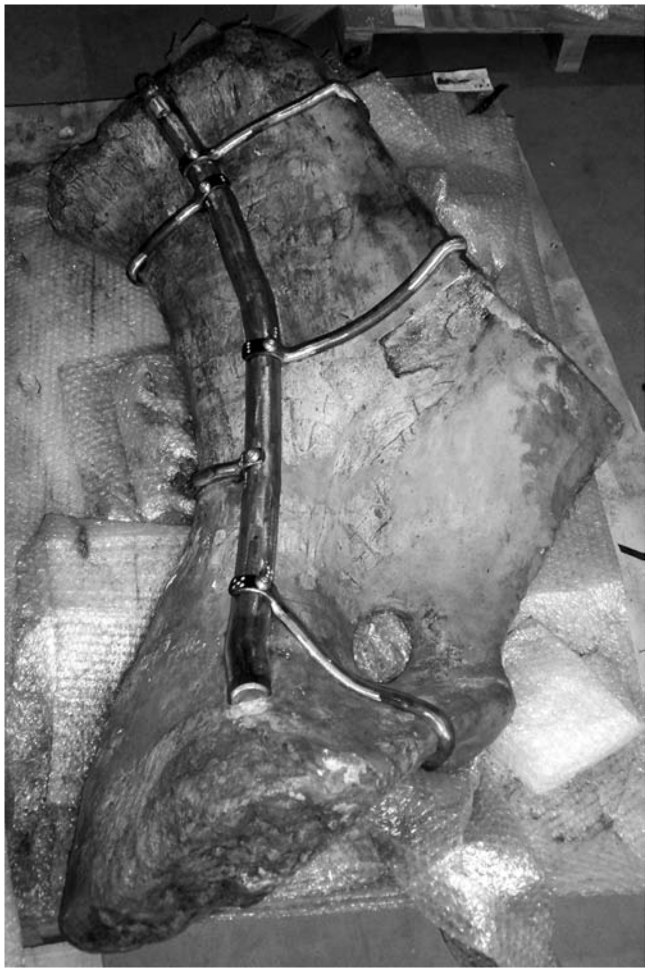

FIGURE 18.3. A steel strut with individually welded and shaped clamps on the left pubis of *Brachiosaurus brancai*. The clamps were screwed to the strut, enabling easy demounting of individual elements for scientific study.

FIGURE 18.4. Comparison of the old skull model of *Brachiosaurus brancai* (A) to the original specimen t 1 (B) and the new model (C) created with the help of 3D laser scanning and rapid prototyping. The new model is much closer to the original.

the vertebral column, the original vertebrae were first molded using the techniques described above. Subsequently, carbon fiber models of three groups of articulated vertebrae (anterior cervicals, posterior cervicals, dorsals), which could be mounted comparatively easily and quickly, were manufactured together with their supporting armature.

Compared to the vertebral column, it was much more difficult to produce an accurate model of the skull. The old skull model (Fig. 18.4A) was unsatisfactory by modern standards, but fabricating a new, improved version proved to be a quite complex undertaking. It appeared that the skull elements of skeleton t 1 were assembled into an elaborate skull reconstruction in 1934. Because of the complexity of this construction and the fragility of the individual bones, it was deemed an unacceptable risk to deconstruct the skull and produce molds from its various components. Therefore, Research Casting International used a Minolta/Konica Vivid 9i 3D color laser scanner mounted on a moveable crane to capture more than 1,000 images of the original skull reconstruction from various perspectives. These images were used to construct a complete virtual 3D model of the skull to be printed out by a rapid prototyping printer. This allowed geometric transformations to be applied before printing, such as size scaling and replacement of missing bones by mirror imaging where contralateral bones were available. For example, the positions of the jugals were corrected at this stage. Because this data set was too large to be handled by most computers, it was divided into smaller parts, each of which was then replicated using a 3D printer. The printed models were reunited to form a complete skull, which was then molded. The mold was used to produce two skull casts, one mounted in the actual skeleton 13 m above ground level and the other on display in front of the mount of the entire skeleton (Figs. 18.4C, 18.5).

Scientific Rationale for Remounting *Brachiosaurus brancai*

As for all the dinosaurs in the refurbished hall, the principal idea behind remounting *Brachiosaurus* was to present the skeleton in a dynamic, lively pose that was set strictly within the limits of likely postures predicted by scientific studies such as those reported on in this volume. At the same time, it was deemed important to retain the majestic appearance of Janensch's classical mount in the center of the hall, which is why the museum chose the concept of a "dinosaur trek," with the skeletons mounted in poses showing them moving slowly toward the visitor as they enter the hall (Fig. 18.5).

Not surprisingly, the remounting of *Brachiosaurus* was by far the most challenging. The Berlin mount is the world's largest skeletal mount with original material, and it has now obtained its rightful place in the *Guinness Book of Records* (Anonymous 2008). A single femur weighs more than 300 kg, and the entire construction, including steel, fossilized bones, and carbon fiber models, adds up to about 5 metric tons. In addition, the schedule for the remounting of the skeleton was tight because of delays in the architectural restructuring of the exhibition halls, leaving no possibility for a test mount and only limited opportunities to correct errors.

The basic design of the *Brachiosaurus* mount is that of a giraffe-like animal with a fully erect neck, resulting in a skull located more than 13 m above the level of the feet (Fig. 18.5). The limbs are mounted in a walking pose, while the tail is held clear of the ground and is slightly curved distolaterally. In the following, potentially controversial issues of the new mount are addressed consecutively.


ARCHAEOPTERYX
DIE WELT IM OBEREN JU

NECK POSTURE

The neck posture of *Brachiosaurus* has been one of the most hotly debated issues in dinosaur paleontology in the last decade (e.g., Sander et al. 2009, 2010; Seymour 2009a, 2009b; Taylor et al. 2009; Christian & Dzemski, this volume). In Janensch's original reconstruction, the head was positioned high above the level of the shoulders, but instead of a vertical orientation, the neck was inclined cranially at about 30° from the vertical. On the basis of computer simulations of intervertebral articulations, Stevens & Parrish (1999, 2005a, 2005b) argued that the neutral pose of the neck of *Brachiosaurus* was closer to the horizontal plane; they rejected the giraffe-like position of earlier reconstructions (Bakker 1986; Paul 1988; Christian & Heinrich 1998). Other workers also agreed with a more horizontal orientation (Frey & Martin 1997; Berman & Rothschild 2005). However, in a series of Research Unit 533 papers on biomechanical calculations of the distribution of forces within the neck and in comparisons with extant long-necked animals, Christian & Dzemski (2007; this volume) showed that the neck could indeed reach a near-vertical orientation (80–85° above the horizontal plane), as is reconstructed in the new mount. During locomotion, forces would have been minimized when the neck was inclined about 30° cranially, corresponding closely to Janensch's original reconstruction. The individual in the exhibition has a walking pose and an almost fully vertical neck. This is less ergonomic than a more inclined neck, but it is still anatomically and behaviorally feasible (Christian 2010; Christian & Dzemski, this volume, for further discussion of this issue). The major argument against the neck raised high is the strain that this would place on the cardiovascular system (Seymour 2009a). In any case, the decision to adopt a fully erect neck posture maximizes the visual impact of the mount and also supports the educational aims of the new exhibition in terms of displaying dinosaurs as active and versatile animals.

RIB CAGE AND STERNUM

The new, anatomically accurate models of the dorsal vertebrae (see above, Technical Solutions for Remounting) had a profound impact on the shape of the rib cage. The ribs formed a rather barrel-shaped trunk in the old mount, but improvements in the accuracy of the position of the rib heads with the diapophyses and parapophyses on the newly modeled vertebrae resulted in a markedly slimmer profile of the trunk (compare Figs. 18.5, 18.6A). In dorsal view, the trunk is teardrop-shaped, reaching its widest point at the level of the fourth dorsal rib and then gradually tapering toward the hips. As a result, the entire animal appears much more slender and elegant, with a considerably reduced volume enclosed by the rib cage. In the exhibition, the mass of *Brachiosaurus* individual S II is cited as up to 50 metric tons, which is based on the mean of previously published estimates (Anderson et al. 1985; Gunga et al. 1995, 1999), preliminary laser scanning measurements, and physiological calculations (Gunga, pers. comm. 2006), as well as on 3D kinematic modeling (Mallison, pers. comm. 2006). However, shortly after the exhibition opened, Gunga et al. (2008) published a refined model that was based on research completed by Research Unit 533, which recalculated the mass of *Brachiosaurus* (still employing the old reconstruction) as approximately 38 metric tons. Consequently, the likely true body mass of a living animal with the same dimensions as that mounted in the new exhibition would have been considerably less and is currently being reassessed (Ganse et al., this volume; Stoinski et al., this volume).

After the rib cage was mounted, we encountered an unexpected problem: the sternal plates were too large to fit between the ends of the anterior ribs when an attempt was made to mount them in a horizontal plane. Such an arrangement is usually preferred for dinosaur sternals and is consistent with the usual orientation in most extant tetrapods. However, because the cartilaginous sternal ribs do not normally fossilize and because complete, undistorted sauropod rib cages with sternal plates in their original position have not been found to date, there is no direct evidence to support a strictly horizontal orientation of the sternal plates in sauropods. In birds, the contralateral halves of the sternum often stand at an angle to the horizontal plane, giving the dorsal side of the sternum a distinct concavity. Hence, we decided to mount the sternals of *Brachiosaurus* in a similar way, with a slight V-like orientation when viewed from the front (Fig. 18.6A). This is also corroborated by the observation that the estimated line of action of m. pectoralis (which runs from the ventral surface of the sternum to the medial side of the deltopectoral crest on the humerus; Remes 2008; Rauhut et al., this volume) would have been more effective with the sternals placed in this position. Alternatively, the problem of accommodating the sternals and rib cage may reflect their origin from two different individuals. However, there is no evidence to support this in the taphonomic data in the records of Janensch's expeditions (Heinrich 1999).

TAIL

In the original exhibition, Janensch opted for restorations in which all sauropods, and even the bipedal dinosaurs *Dysaloto-*

FIGURE 18.5. *Opposite page*: Right anterolateral view of the new mount of *Brachiosaurus brancai,* on display since July 2007. Note the walking pose, the vertical forelimbs with backwardly directed elbows, and the tail held clear of the ground.

FIGURE 18.6. Close-up views of the shoulder girdle of the new mount of *Brachiosaurus brancai.* (A) Cranial view. (B) Left lateral view. The scapular blades are inclined about 60° from the horizontal. Note the space between the rib cage and the scapula, illustrating the volume of the serratus and subscapularis muscles. Because the improved models of the dorsal vertebrae led to a narrower trunk, the sternal plates had to be arranged in a V-like manner to fit between the distal ends of the ribs. See text for further explanations.

saurus, Plateosaurus, and *Elaphrosaurus,* were reconstructed with their tails resting on the ground. This implied that the tail was dragged behind the animal during locomotion in a fashion similar to that of modern lepidosaurs. Such a reconstruction was widely used during the first half of the 20th century and reflected contemporary interpretations of dinosaurs, especially sauropods, as sluggish, lizard-like creatures (e.g., Hay 1908, 1910, 1911; Tornier 1909; Abel 1910; Holland 1910; Matthew 1910). However, examination of modern archosaurs with a long tail (i.e., crocodilians) reveals that even these forms carry their tail above the ground, with only its distal tip occasionally contacting the substrate. Since the time of the Tendaguru expedition, thousands of examples of dinosaur tracks and traces have been discovered and recorded (e.g., Lockley 1991). Many of these have been attributed to sauropods, and almost without exception, they lack any evidence of tail drags. However, it was only fairly recently that the significance of these tracks was fully appreciated (e.g., Bakker 1971, 1986) and incorporated into modern reconstructions of dinosaurs, which now are almost always shown with the tail held in the air in a near-horizontal position. This arrangement has a number of biomechnical advantages: the tail can serve as a counterbalance for the anterior half of the animal and may facilitate rearing (Mallison, Chapter 14, this volume). Moreover, the principal muscle serving to propel the animal during terrestrial locomotion, the m. caudofemoralis longus (Gatesy 1990, 1995; Hutchinson & Gatesy 2000), which originated from the anterior one third of the tail, would have been most effective with the tail held horizontally. Otherwise, the distance between origin and insertion of this muscle would have been too short for efficient locomotion (Carrano 1998, 2000, 2005; Rauhut et al., this volume; Mallison, Chapter 14, this volume). Hence, there is both ichnological and biomechanical evidence to support the idea that sauropods held their tails clear of the ground, and this is reflected in the newly mounted *Brachiosaurus* and other dinosaurs in the exhibition hall.

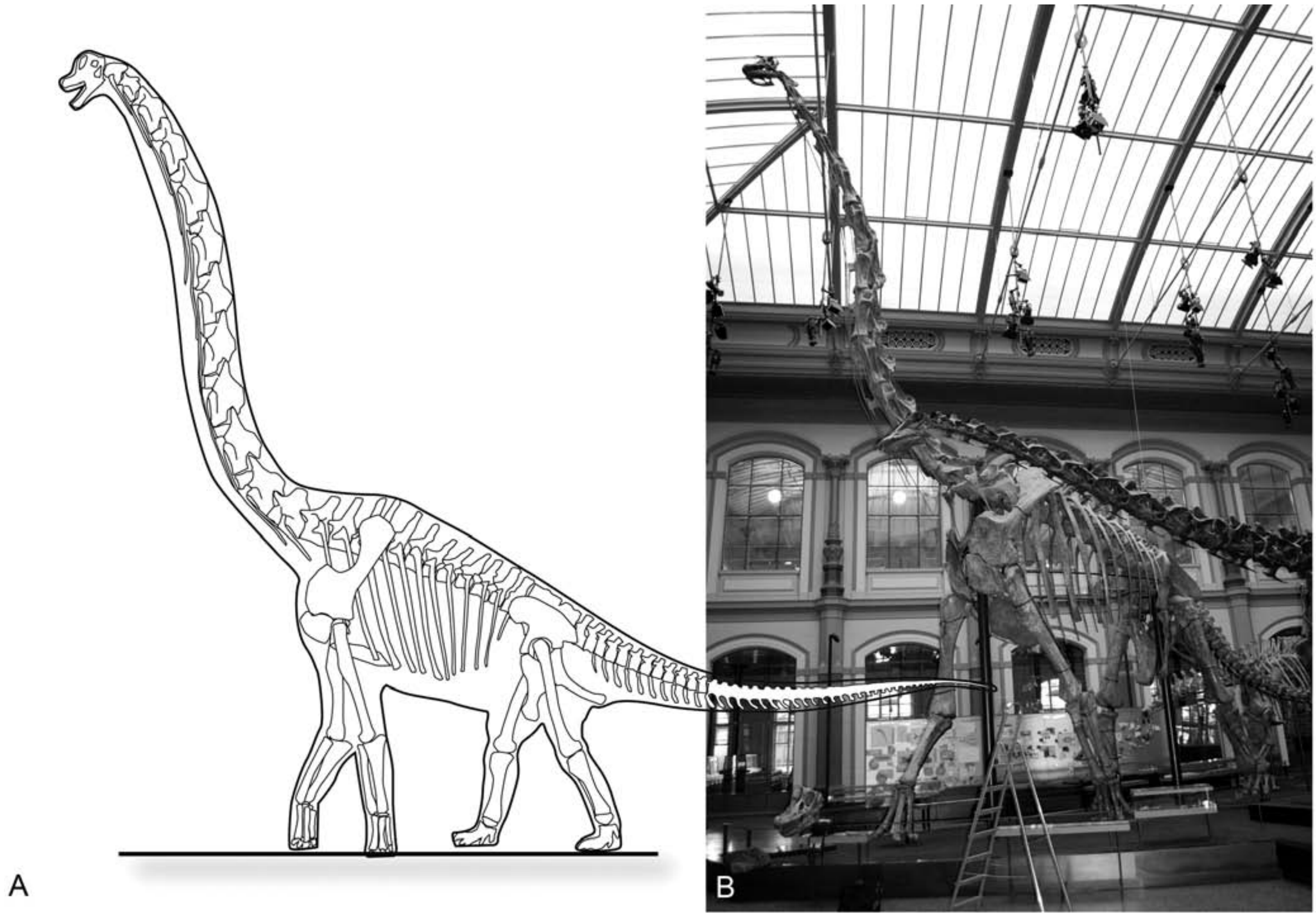

FIGURE 18.7. Comparison of the originally planned walking pose (A) and the actual mount (B). Because the anterior steel column proved to be too short during the mounting process, the left forelimb had to be retracted further in order to fit between glenoid and floor level. This makes the animal appear to be walking faster. See text for further explanations.

SHOULDER GIRDLE

The position of the shoulder girdle in sauropods has become a matter of debate in recent years (Schwarz et al. 2007). Observations of partially articulated skeletons (Gilmore 1925) and impressions of the rib cage have led to suggestions that in life, the sauropod scapula was subhorizontally oriented (Parrish & Stevens 2002), a position already incorporated by Janensch in the original mount. However, the position of the scapula, even in fully articulated skeletons, may have been altered by postmortem desiccation of muscle tissue (Schwarz et al. 2007). Impressions of the scapula on dorsal ribs are most likely due to diagenetic effects because the scapula does not articulate with the rib cage in extant tetrapods but instead is widely separated from the ribs by muscle tissue (m. subscapularis, mm. serrati). On the basis of functional considerations, Schwarz et al. (2007) argued that the scapula was rather steeply inclined caudodorsally at an angle of about 50–60° to the horizontal. Remes (2006, 2008) came to the same conclusion and added a phylogenetic perspective, demonstrating the absence of any rotation toward a subhorizontal orientation throughout sauropodomorph evolution. Therefore, the scapula of *Brachiosaurus* was mounted at an inclination of about 60° to the horizontal, with the scapular part of the glenoid facing ventrally. This brought the glenoid into a position distinctly ventral to that in the old mount, which resulted in a steeper inclination of the back and a somewhat higher position for the base of the neck.

LIMBS

The position of the limbs is crucial for conveying the impression of a skeletal reconstruction in a static stance or in a dynamic pose. A walking position was therefore the natural choice for the new *Brachiosaurus* mount and consistent with the concept of the exhibition. However, mounting the limbs also caused the majority of problems.

Initially, it was planned to mount *Brachiosaurus* as if it were walking at a slow speed (Fig. 18.7A). The body would have been supported by the right forelimb and left hindlimb in contact with the ground, while the left forelimb and the right hindlimb would have been elevated in the phase of protraction. This arrangement was inspired by the lateral footfall pattern used by elephants, which is identical to the gait known as *toelt* in, for example, Icelandic ponies (Hutchinson et al. 2006). In such a configuration, there may have been enough space between the fore- and hindlimbs to allow visitors to walk beneath the rib cage, a novel exhibition feature that was discussed during the development phase of the exhibition. However, in the course of the mounting process, it was found that as a result of a miscalculation, the steel tube forming the front supporting pillar was too short. To correctly increase the length of the support, the already mounted elements (at this point in time the dorsal vertebrae, the sacrum, and the hindlimbs) would have had to be dismounted again followed by welding an extension to the front pillar. In addition, the sacrum and ilia would have had to be redesigned because extending the front pillar would have steepened the angle of the dorsal vertebral column. Because the schedule for mounting the skeletons was tight, this was not an option. It was decided instead to further retract the left forelimb so that it could be accommodated between the base of the mount and the glenoid joint. As a result, the entire mount became even more dynamic in appearance, primarily because the increase in step length of the forelimbs suggests a rapid walk rather than a slow toelt gait. This mode of locomotion resembles a pace (e.g., as in camels), a gait probably not typical for *Brachiosaurus;* however, this had no negative effect on the realistic appearance of the mount in the eyes of the museum visitors. Another consequence of this repositioning was a reduction in the gap between the forelimbs and the hindlimbs, excluding any possibility of a passageway beneath the mount for visitors.

A second problem was encountered during the mounting of the limbs. This also stemmed from the improved reconstruction of the rib cage and shoulder girdle, which imposed a bilateral symmetry on the cranial half of the torso fixing the positions of the glenoid joints. However, the limb elements themselves were not entirely symmetrical; the damaged left humerus had been supplemented with plaster for the original mount. This resulted in humeri of different lengths, with the complete right humerus being about 5 cm shorter than the partially reconstructed left humerus. As a consequence, there was sufficient room to mount the right limb with a substantial gap between the distal humeral condyles and the lower limb, representing space for the articular cartilage, while on the left side the humerus, radius, and ulna were mounted in contact with one another.

Ultimately, the problems encountered, and their solutions, had only a minor impact on the overall appearance of the animal, and are only likely to be detected after prolonged study of the mount. Despite its size, from all perspectives, the new *Brachiosaurus* mount is suggestive of an elegant, giraffe-like animal, captured in a dynamic stance and gait that contrasts quite sharply with the more static reconstruction from 1938.

Acknowledgments

We thank all participants in the ERDF (European Regional Development Fund) exhibition project for the excellent manner in which the collaboration was conducted, and without which the remounting of *Brachiosaurus* and the success of the new exhibition would not have been possible. We also thank all those institutions that provided funding, including the European Regional Development Fund, the Lotto Foundation, and the state of Berlin. K.R. thanks the Deutsche Forschungsgemeinschaft for funding his research through project RA 1012/2. This is contribution number 77 of the DFG Research Unit 533 "Biology of the Sauropod Dinosaurs: The Evolution of Gigantism."

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