

Nomenclature

The mounted *Diplodocus* skeleton at the Carnegie Museum does not have a specimen number of its own. It is often referred to loosely as CM 84, since that is the specimen that contributes most of the original fossil material to the mount, or, more carefully, as CM 84/94/307, since those are three of the four specimens that contribute fossil material. In this paper, we will refer to this mounted skeleton as “the Carnegie mount”; when we refer to CM 84, we mean the particular individual specimen, not the mount. When referring to the various cast mounts, we refer to them by the name of the city that they were originally mounted in (e.g., the London cast, the Berlin cast, the Vernal cast); the sole exception is that we refer to the Russian cast by the name of the nation in which it resides, as because it was initially installed in St. Petersburg but currently stands in Moscow.

The diplodocine specimen initially designated CM 662 was traded to the Cleveland Museum of Natural History in November 1956, because Carnegie Museum director Graham Netting had instructed head of vertebrate paleontology J. LeRoy Kay to trade large dinosaur specimens due to lack of storage space (Tschopp et al. 2019:10). Around the same time (1854–56), accession records show that the Carnegie Museum acquired 10,803 bird specimens from the CMNH, likely in exchange for the diplodocine. In Cleveland the diplodocine skeleton was given the specimen number CMNH 10670. In 1963, however, the specimen was sold for \$15,000 to the Houston Museum of Natural Science, where it was cataloged as HMNS 175. (The CMNH’s *Haplocanthosaurus* [now the holotype of *H. dellsi*] was excavated between 1954 and 1957 (McIntosh and Williams 1998:4–5], and it is possible that the diplodocine CMNH 10670 was sold because it became apparent that there was not enough space to mount two large sauropods.) The Houston Museum mounted the skeleton in 1975 –

confusing? Maybe put the abbreviation 1st first?
Carnegie Museum?

ironically completing it with elements cast from second-generation Carnegie *Diplodocus* molds supplied by the Utah-based commercial casting company Dinolab, Inc. (Taylor et al. 2023) — then restored and remounted it between 2013 and 2015. For simplicity, we refer to this specimen throughout by its original designation CM 662, as it was under this specimen number that most of its role in this story was played out.

A distinction is made between molds and casts. A mold is a negative structure made from an original specimen (or, less commonly, from a cast or a sculpture), in which the spaces inside the mold match the shapes of the original specimen. A cast is a positive structure, a copy made of a specimen made by filling a mold, and its shape matches that of the original specimen.

Vertebrae are designated as follows, for a vertebra at position *n* in a part of the spinal column: cervical vertebrae *Cn*, dorsal vertebrae *Dn*, sacral vertebrae *Sn*, and caudal vertebrae *Can*.

When measurements are quoted in both imperial and metric units in either order, e.g., “84 feet (= 25.6 m)” or “23.5 m (= 77 feet)”, the first measurement is as originally reported, and the second is converted.

Institutional abbreviations

- AMNH — American Museum of Natural History, New York, New York, USA.
- BMNH — British Museum of Natural History, London, England. (Now the Natural History Museum, using the abbreviation NHMUK.)
- BSP — Bayerische Staatssammlung für Paläontologie und Geologie, Munich, Germany.

feet for a femur, despite including an illustration of Reed standing next to the femur that showed him slightly taller than it. The article optimistically extrapolated a total length of 130 feet, hip height of 35 feet and shoulder height of 25 feet. Coggeshall (1951a:238) implies that Reed had a reputation for inflating the sizes of his finds, so it is likely that Jones was merely relaying dimensions relayed to him by Reed.

A colleague, Arthur

On 1 December 1898, the much more widely read *New York Post* published an anonymously condensed version of Jones's article titled "The Dinosaur of Wyoming" (Anonymous 1898a). This came to the attention of industrialist and philanthropist Andrew Carnegie (Figure 2A), who at age 63 was beginning to turn his attention away from industry and had become founder and funder of the Pittsburgh museum that bore his name. Excited by this report, Carnegie scrawled on a copy "My Lord — Cant you buy this for Pittsburgh — try. Wyoming State University isn't rich — get an offer — hurry AC" (Figure 3). He sent this to William J. Holland (Figure 2B), director of the Carnegie Museum, and followed it with a cheque for \$10,000 (about \$370,000 today) (Holland 1930:84). (Many accounts — including that of Holland (1930:83) himself — credit a later article in the *New York Journal and Advertiser* (Anonymous 1898b), which depicts a "Brontosaurus giganteus" in bipedal posture, peering into an 11th story window, for triggering Carnegie's interest, but Carnegie's handwritten note shows that the earlier article was the significant one.)

Holland used Carnegie's money to hire experienced field paleontologists away from other museums: Reed from the University of Wyoming and Jacob L. Wortman and Arthur S. Coggeshall from the AMNH (Coggeshall 1951a:238). He sent them out to collect Reed's "Most Colossal Animal." It soon became clear, however, that this discovery consisted only of the proximal third of an apatosaurine

complete sacrum S1–S5, caudal vertebrae Ca1–12, 18 dorsal ribs, both sternal plates, left scapulocoracoid (not right as stated by Hatcher), almost complete pelvis, right femur, and two thin bones of uncertain identity which Hatcher thought might be clavicles (McIntosh 1981:20).

In 1900, Olaf A. Peterson (Figure 2C) and Charles W. Gilmore collected another, slightly smaller, specimen of the same sauropod species from the same quarry (Hatcher 1901:3). This specimen was designated CM 94. It consisted of nine cervical vertebrae, nine dorsal vertebrae, the sacrum, some number of caudal vertebrae (39 as reported by McIntosh 1981, but see below), fragments of dorsal ribs, five chevrons, both sternal plates and scapulocoracoids, the complete pelvis, the left femur, and the right tibia, fibula, astragalus, and pes (McIntosh 1981:20).

Both specimens were prepared out of their matrix by Arthur S. Coggeshall (Figure 2D) and his team (Figure 6).

On 15 May 1901 (Nieuwland 2019:46), the classic description of both these specimens of *Diplodocus* was published (Hatcher 1901), written by John Bell Hatcher (Figure 2E), the Carnegie Museum's head of paleontology. This monograph illustrated CM 84 in some detail and named it as the holotype of the new species *Diplodocus carnegii* in honor of the museum's sponsor. (Hatcher's (1901:56–57) diagnosis of the new species is arguably rather thin, depending almost entirely on the orientation of the neural spines of anterior caudal vertebrae, but *is this necessary?* renowned saurropod expert John S. McIntosh considered *D. carnegii* legitimately distinct from the type species, *D. longus* (Rea 2001:ix), and this separation has been widely followed.) The illustrations included a skeletal reconstruction of *Diplodocus* (Hatcher 1901:plate XIII; Figure 7).

Agostini continued to work for the Carnegie Museum for another 44 years until retiring in 1948 (Krishtalka 1988:15), and remained an important part of the operation; for example, the museum's Annual Report for 1934 states that "Mr. Agostini made some excellent moulds [sic] and casts of the skulls of *Apatosaurus* and *Diplodocus* during the year and one of these skull casts has been mounted on our great skeleton of *Apatosaurus* which stands in the exhibition hall" (Carnegie Institute 1934:40).

Although we, and other sources, speak freely of molds and the casts made from them, the reality is rather more complex. As Holland (1903) wrote in a letter to Carnegie, "the condition of our bones [...] is such that we cannot without endangering the specimens in some cases pour plaster about them to make piece molds. [...] It will become necessary for us to carefully model in sculptor's clay a number of at least the vertebrae, and then from the models make molds, from which an indefinite number of reproductions can in future be made." Thus the molds of at least some of the complex vertebrae are actually molds of sculptures, not of the original bones; and so the casts created from them do not precisely match their original fossil counterparts.

In the early summer of 1904, the cast created for the British Museum was temporarily mounted as a trial in the Main Hall of the Pittsburgh Exposition Society at The Point in downtown Pittsburgh (Figure 10; photograph in Nieuwland 2019:figure 3.1). At this point, it was the only available building in the city big enough to house the skeleton, the museum's new Dinosaur Hall not yet having been completed. The work was led by Coggeshall, who was responsible not only for executing the mount but also for creating the techniques. At the start of the 20th Century, there was little prior art for mounting large fossil skeletons. The most experienced crew was that responsible for mounting all the Bernissart *Iguanodon* specimens in Brussels (Belgium), but they maintained little to no contact

outside the francophone world, and guarded their secrets. Coggeshall had to work out for himself how the cast bones could be mounted in a lifelike posture, informed by some experience with fossil mounts in his previous post at the AMNH, but nothing on the scale of a complete sauropod. The mounting was carried out by a team of three: Coggeshall himself aided by Agostini and L. S. Coggeshall (Coggeshall 1951b:276), the latter almost certainly Arthur's brother Louis.

The men doing this type
of work consulted with one
another in person
and in correspondence

By 4 June, Hatcher (1904a) was able to write that “The *Diplodocus* skeleton is rapidly assuming form in the Exposition building, and we shall, I think, have the mount complete by the 1st of July,” and on 14 June “The mounting of our skeleton of *Diplodocus* in the Exposition building is rapidly nearing completion and in two weeks more it will be an accomplished fact” (Hatcher 1904b). The work was on the predicted schedule, and the skeleton was shown to an invited party on 29 June, then to the public on the 30th, before being disassembled again on the 2 July. On the very next day, Hatcher died of typhoid fever at only 42 years of age – but he had at least seen the skeleton that he had described in its mounted state before his death (Holland 1906:226). Carnegie field worker William H. Utterback (1904) wrote that Hatcher’s sudden death was “a sad blow indeed. Having been the warmest of friends for many years and associated with him in this work under the most trying of circumstances I feel his loss more than words can express [...] The loss to science and to our institution will never be fully realized.”

The Carnegie Museum’s *Diplodocus* cast was therefore (albeit briefly) the first mounted sauropod in the world, eight months ahead of the AMNH’s composite *Brontosaurus*, AMNH 460, which was to be unveiled on 16 February 1905 (Brinkman 2010:104).

Joseph of the Austrian-Hungarian empire had requested the gift from Carnegie, Steindachner had little option but to find space for it somewhere. This proved difficult – a mooted new building was cancelled due to lack of funds, and in the end the skeletal cast was mounted in a three-meter-wide corridor (Nieuwland 2019:216–219). The emperor was present for the unveiling on 24 September 1909, but the ceremony appears to have been a rather unspectacular affair, lasting only fifteen minutes. The novelty of the Carnegie *Diplodocus* was wearing off, and most of the subsequent gifts would be received with less than extravagant gratitude.

On 27 October 1909, the last of the original batch of five casts was mounted in Bologna, Italy. While the name of King Victor Emmanuel III was invoked, gratifying Carnegie’s desire to be seen to be responding to requests from heads of state, Giovanni Capellini, the director of the Aldrovandi museum at the university, was the true originator of the request (Nieuwland 2019:227–228). Although previously casts had been erected in only the capital cities of the countries they were donated to, Bologna was considered an appropriate venue, perhaps partly because Università di Bologna is the oldest continuously operating university in the world.

The original casts had now all been given away, but requests kept coming in, which led Carnegie and Holland to have another five casts prepared. The first planned donation, to Rio de Janeiro, was thwarted by the ~~tumultuous~~ quagmire of Brazilian politics. However, a cast was installed in St. Petersburg, Russia in June and July of 1910, again supervised by Holland, who confided to Carnegie that he was “really getting tired of ‘the old Dip’” (Nieuwland 2019:232), together with Coggleshall. Holland (1910b, 1913:249–250) told colorful and somewhat contradictory tales of the in-progress mount’s catastrophic collapse when visited by a party of officials, and these have been retold (e.g.,

finished. The Argentinian president was unable to conduct an official opening himself, because the departure from Buenos Aires to La Plata would have involved a formal handing over of authority to the vice president (Coggeshall 1951c:314–315). The donation received very little publicity at the time, *could say more about this*, although Holland's memoir of the trip gave it some notoriety afterward (Holland 1913).

Shortly after the preparations for the La Plata cast had begun, in January of 1912, the Spanish ambassador was ordered to request a *Diplodocus* from Carnegie on behalf of King Alfonso XIII (Pérez García and Sánchez Chillón 2009). In marked contrast to Argentina, public interest in the Spanish *Diplodocus* was far greater than it had been in any country since France (Nieuwland 2019:243–246). The Madrid cast was prepared concurrently with the Argentine cast and sent to Spain in September of 1913. Holland and Coggeshall, who arrived in Madrid on 11 November 1913, were treated as guests of honor, and took longer to complete their work than they had in La Plata due to numerous social obligations (Coggeshall 1951c:314). The cast was complete by 28 November and donated in absentia to the monarch who was nominally the cast's recipient. On 2 December 1912, Queen María Cristina and her daughter, Infanta Beatriz, opened the new museum hall containing the *Diplodocus*, which was perhaps the closest thing to an official unveiling of this specimen (Pérez García and Sánchez Chillón 2009:140).

The outbreak of World War I put an end to Carnegie's arbitration campaign, and affected him deeply as a person: he retreated almost entirely from public life to his New York apartment, where he died in 1919. As a consequence, the *Diplodocus* donation scheme came to a halt. It had been a great success, however: Holland was later to write to Carnegie's widow Louise that "Your dear husband once said to me: 'I never got as much pleasure or as much publicity from so small a sum of money as

you might want to introduce this more thoroughly earlier in the paper

I have through your happy thought of making replicas of the animal, which bears my name'." (Holland 1928).

By the time of his death, Carnegie had mostly succeeded in giving away his fortune, and it soon became clear that the museum's previously luxurious financial circumstances were to be exchanged for relatively spartan ones. The continuing funding from Carnegie's trust "certainly did not allow the natural history museum to keep up its competition with New York's AMNH" (Nieuwland 2019:250). As noted by Gangewere (2011:24), Carnegie's gifts to his Institute and Library during the last 20 years of his life amounted to \$11,729,470 (about \$200,000,000 in current dollars); but in the 20 years after his death, only an additional \$1.4 million (in the dollars of the time) was provided - at 12% as much - and relatively little of this would have gone to the Natural History Museum. While Holland had considered closing the Carnegie Quarry, near Vernal, as early as 1917 (Carpenter 2018:13), the reduction in funding must have played some part in the eventual decision to abandon it in 1922.

Around this time, the molds from which the casts had been made went into storage, and were not used again for forty years (Untermann 1959:364). However, of the ten casts that had been created from them, two still remained in Pittsburgh, though incomplete.

In 1922 Holland retired from the museum, aged 74, but his involvement with *Diplodocus* would require one last trip. Seemingly unaware of rising political tensions between the United States and Mexico, he supported a request for a *Diplodocus* cast from the Mexican ambassador in a letter to Louise Carnegie in 1927 (Rea 2001:204-207). She was persuaded to spend part of the money in the *Diplodocus* restoration fund on having the last two casts completed and to gift one of them to Mexico. On 6 April 1930, at the age of 81 (not 80 as stated by Nieuwland 2019:250), Holland arrived in

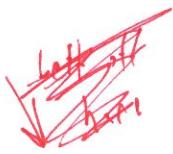
Mexico City together with Arthur Coggeshall's brother Louis, to set up his last *Diplodocus* at the Universidad Nacional Autónoma de México, the oldest university in the Western Hemisphere. He was compelled to return home shortly before the mount was completed (Rea 2001:209), and the task was finished by Louis Coggeshall, but there was no formal unveiling ceremony in Holland's absence. A year and a half later, Holland died of a stroke on 13 December 1932.

The remaining *Diplodocus* was completed, boxed, and shipped to Munich's Bayerische Staatssammlung für Paläontologie und Geologie in November and December of 1934, completing an exchange for fossils received from Germany five years previously (Carnegie Institute 1934:40). On arrival, however, the cast was not mounted, but instead stored in the basement of the Alte Akademie, which also housed the rest of the paleontological collections. The replica was long assumed to have been destroyed during World War ~~Two~~^{II}, specifically during a British Royal Air Force bombing in April 1944, along with the *Spinosaurus aegyptiacus* holotype BSP 1912 VIII 19 and other dinosaur remains from Egypt. However, the cast had been removed from the building before the bombing raid, and while the elements themselves were not destroyed, the record of where they had been moved to was lost. It now seems the cast was taken to an abandoned convent on the outskirts of Munich. It is believed that a group of hippies, holding parties in the convent during the 1960s, found some cast bones, took them home, and attracted the attention of authorities who then discovered the crates (sources who wish to remain anonymous, pers. comm., 2022). At any rate, the cast was returned to the Munich museum in 1977 but has remained in storage ever since. Calls for it to be mounted as one of the attractions of a new museum at the Nymphenburg castle came to nothing, partly because the

him) the holotype of the new species “*Diplodocus*” *hayi* (Holland 1924:399). The species has since been made the type species of the genus *Galeamopus* (Tschopp et al. 2015:267).

- The remainder of the skull was based on USNM 2673 (illustrated by Holland 1906:plates XXIII–XXV), the specimen on which Marsh (1896:175–179) had primarily based his description of the skull of *Diplodocus*. With the USNM’s permission, the Carnegie Museum made a cast of this skull, of which only the left side had been fully prepared. They used this to restore the unprepared right side. Ironically, this skull has since been referred by Tschopp et al. (2015:228) to *Galeamopus*, meaning that both fossils on which the Carnegie mount’s skull were based are now considered to belong to that genus rather than to *Diplodocus*.

Holland (1906:228–230) was ahead of his time in determining the orientation of the skull as being strongly inclined relative to the cervical column. Citing Marsh’s (1896:175–176) observation that “the occipital condyle [...] is placed nearly at right angles to the long axis of the skull,” Holland (1906:229–230) rightly observed that “to place the skull with its longer axis in a line parallel with that of the cervical vertebrae was a mechanical and anatomical impossibility [and] involves the dislocation of the neck.” Instead he arranged for the skull of the London cast to be strongly inclined downwards. Yet when the Senckenberg Museum in Frankfurt, Germany opened in 1907, displaying a bas-relief half-mounted *Diplodocus* skeleton supplied to it by the AMNH, the skull was oriented incorrectly, with its long axis parallel to the neck (photograph in Anonymous 1907:figure 1), and it remains in this impossible posture even in a subsequent remount (see, e.g., Norman 1985:188–189). Over a century later, it is still common to see artwork of *Diplodocus* (and other sauropods) with their heads parallel to



Changes made to the mount at the Carnegie Museum

Replacement of skull with replica of CM 11161

The first known change made to the Carnegie mount was the replacement of the original sculpted skull that had been based on CM 662 and USNM 2673. We have been unable to locate records stating which skull was used in the replacement, but it is still in place today, and judging from first-hand inspection, it is evidently based on CM 11161. This specimen is a complete and superbly preserved diplodocine cranium and mandible (often, though not always, referred to *Diplodocus longus*; see, e.g., Tschopp et al. 2015), described and illustrated in detail by Holland (1924). It was discovered on Thanksgiving Day of 1912 from the Carnegie Quarry at what is now Dinosaur National Monument in Utah (McIntosh 1981:17).

Curiously, the skull replacement is not mentioned in McIntosh's (1981) account of all the dinosaur specimens reposed at the Carnegie Museum at the time, and in particular not in the section on the *Diplodocus* mount on page 20. Given McIntosh's habitual thoroughness, this omission from his account of the mounted skeleton is anomalous.

In the absence of extant records, it cannot be precisely stated when this replacement was made, or even whether the current skull is a cast or a sculpture. Carnegie Museum annual reports from 1912 (when CM 11161 was discovered) up until the turn of the millennium make no mention of the use of this specimen as the basis of a new skull for the mount. It was certainly available for Serafino Agostini to have used when he “made some excellent moulds [sic] and casts of the skulls of *Apatosaurus* and *Diplodocus*” in 1934 (Carnegie Institute 1934:40). However, since this report mentions that one of those casts was used to provide a skull for the mounted *Apatosaurus* CM 3018 but no mention is

made of a cast used for the *Diplodocus* mount, we can assume this was probably not done, and that the substitution must have happened at a different time. (Berman and McIntosh (1994:92) state that the incorrect *Camarasaurus* skull replica was mounted on the Carnegie *Apatosaurus* CM 3018 in December 1932, but if the skull in question was that created by Agostini in 1934, this cannot be correct.)

At any rate, the new *Diplodocus* skull was in place by 1947, as it is shown in a photograph of the mounted skeleton included in a Carnegie Magazine article of that year about Serafino Agostini (Seneff 1947). So the replacement must have happened some time between 1912 and 1947.

Regarding whether the present skull is a cast or a sculpture: it captures bone texture, including damage, very accurately (Figure 15). The mounted skull includes the sclerotic ring in the left orbit but omits this structure from the right orbit. This is the condition in the original CM 11161 fossil (compare Tschopp et al. 2015:figure 1D with these authors' figure 3E), and while this asymmetric preservation would be replicated by a cast, it would not likely be included in a sculpture. For these reasons, we believe the skull on the mount is a cast.

likely?

It is possible that the atlas was replaced at the same time as the skull (see above).

Suspension of neck

In a photograph of the mounted *Diplodocus* taken some time between 1985 and 1999 (Figure 16), the neck is shown suspended from the ceiling. This is in contrast to older photos in which it is supported from beneath by a tripartite pole (Figure 14). However, the tail remained in its original dragging posture.

It is possible that the change in neck support was made to free the space under the neck and so make room for the tail of the *Allosaurus* mount CM 11844 that was at some point moved to a position in front of the *Diplodocus* mount from its original 1938 position behind and to the right of the tail of this sauropod. (The tail of the repositioned *Allosaurus* can be seen at lower left in Figure 16.) But as the date of the *Allosaurus* move is not known, this does not help us determine when the *Diplodocus* neck support was changed.

1999 replacement of forefeet with CM 662 replicas

The forefeet of the original mount were sculpted from those of a camarasaurid specimen AMNH 965, the forefeet of *Diplodocus* being unknown at the time. They were reconstructed in a semi-plantigrade posture now known to be inaccurate, and reconstructed with unguals on each of the first three digits (Figure 14A-B, Figure 17A), although it was already known at the time of mounting that sauropod forefeet had claws on only the first digit (Osborn 1904:181). ~~Only~~ ^{were finally} nearly a century later, in the second quarter of 1999, ~~were~~ these errors remedied, when Norman Wuerthele and one of us (Henrici) made casts of the forefeet of CM 662 (Carnegie Institute 1999:2), which were installed on the mount shortly thereafter (Figure 17C). Although CM 662 was originally a Carnegie Museum specimen, by this point it was at the Houston Museum of Natural Science.

2007–2008 refurbishment of the dinosaur exhibition

By the turn of the millennium, the Carnegie Museum's original 1907 Dinosaur Hall had been in place for nearly a century with no major renovations. Plans were laid in the early 2000s not just to renovate the hall but also to add additional space in a newly constructed atrium, add more mounted skeletons and other specimens, and remount the existing skeletons. The expansion was announced on

Thursday 11 April 2002 (Siemers 2007); architects were hired in 2004 (Hopey and McNulty 2007) and the hall was closed for refurbishment on Friday 11 March 2005 with a special event that evening marking the occasion (Horne 2005).

The new dinosaur exhibition, titled *Dinosaurs in Their Time*, was opened in two phases: the majority of the exhibition in November 2007, and the Hell Creek Formation (i.e., latest Cretaceous continental) section in June 2008. The Jurassic section, including *Diplodocus* and the *Apatosaurus louisae* holotype CM 3018, was opened for ticketed previews at 6 am [sic] on Saturday 17 November 2007 (Roddy 2007) and for general admission on 21 November 2007 (McNulty 2007). *why not correct this?*

As part of the broader renovation project, the Carnegie *Diplodocus* was remounted in a new, more dynamic posture by Phil Fraley Productions (PFP; Figure 18), and several changes were made to the materials incorporated in the mount, detailed in the following sections.

Forefeet WDC-FS001A

As noted above, CM 662 has been recognized since 1924 as representing a different species from CM 84, namely “*Diplodocus*” *hayi* (Holland 1924:399). It was for this reason that, unlike their predecessors, the sculpted forefeet based on those of CM 662 remained in the Carnegie mount for less than a decade. During the 2007 remount, the forefeet were replaced once more, this time with scaled-up sculptures based on casts of the putative *Diplodocus carnegii* manus WDC-FS001A described by Bedell and Trexler (2005) (Figure 17D). At this point the old CM 662-based sculptures were moved into the collection and given their own catalog number, CM 81786.

Since the replacement of the CM 662-based forefeet, the species *hayi* has been moved to its own genus, *Galeamopus* (Tschopp et al. 2015:267), further justifying the decision to replace these forefeet

with those of *Diplodocus* proper. However, the phylogenetic analysis of Tschopp et al. (2015:229–230) found WDC-FS001A to be a basal diplodocine not included in *Diplodocus*, suggesting that even this third set of replica forefeet may not be correct.

Forelimb elements from BYU material

The initial version of the Carnegie mount included the obviously incorrect left humerus, radius, and ulna of the camarasaurid specimen CM 21775 (Figure 14B, E). These remained in place into the 1930s (Figure 14A) and are generally said to have been retained until the 2007 remount (e.g., Tschopp et al. 2019:33). This is most likely correct, but it is notable that in a photograph taken some time between 1985 and 1999 (Figure 16), the left humerus appears about as long and as gracile as the right, suggesting the possibility that it may have been replaced some time before then. The apparent difference in forelimb disparity between the 1907 iteration of the mount and its 1980s/1990s counterpart may however be explainable by the different camera angles and the foreshortening effects produced by their perspectives on the two humeri.

At any rate, and as discussed above, the right humerus, radius, and ulna, having been based on the diplodocine CM 662, were always a much better, although not perfect, match for CM 84. For this reason, the humeri, radii, and ulnae on both sides were slated to be replaced in the 2007 remount. Various enquiries regarding potential replacement elements were made, but most proved unfruitful:

- The Smithsonian (National Museum of Natural History) has a fine partial skeleton of *Diplodocus*, USNM V 10865, which includes both humeri and ulnae and the right radius, with the right forelimb having been found in articulation (Gilmore 1932:19–20). However, that institution's vertebrate paleontology department had no casts of these elements on hand and

the undermanned vertebrate paleontology department did not have the necessary resources to mold and cast replicas of the required limb bones.

- The Sauriermuseum Aathal in Switzerland has several diplodocid specimens. The owner, Kirby Siber, noted that between 1990 and 1995 “we collected seven *Diplodocus* specimens, all partial skeletons and all without forelimbs! It looked to us like *Diplodocus* did not have any!” Tetrapod forelimbs are typically lost early in taphonomy (Hill 1980:133, Walker 1980:196), and this seems to be especially true in *Diplodocus* (Siber, pers. comm., 2022). Siber proposed that limb bones of their specimen XL, about 90% the size of CM 84, might be of use. The cost of purchasing the original fossils proved prohibitive, and the option of casting was therefore explored. However, these plans, too, were ultimately abandoned, as XL did not include a radius and its ulna had been misplaced.
- The Wyoming Dinosaur Center had relevant elements but they were all too small (about 60% the size of CM 84).
- Enquiries were made about the mounted *Diplodocus* DMNS 1494 at the Denver Museum of Nature and Science. This specimen had been received from the Carnegie Museum in exchange for fossil mammals, and mounted by Philip Reinheimer during the mid-1930s with a Works Progress Administration crew, before being remounted more recently by Ken Carpenter and Bryan Small (Carpenter, pers. comm., 2022). This line of enquiry was abandoned when it became apparent that the forelimbs of DMNS 1494 were casts of the Carnegie’s original, incorrect forelimb material!

This section - while interesting - could be cut for length

The AMNH, Dinosaur National Monument, and the Yale Peabody Museum were all also suggested as possible sources of replacement humeri, radii, and/or ulnae, but none was able to help. Sauropod limb specialist Ray Wilhite was consulted, and concluded from his data that the choice was between elements that were the right size but poorly preserved, or well preserved but the wrong size.

Since it would be necessary to combine elements from multiple specimens to create complete forelimbs, Scott Lucas of PFP, in consultation with Wilhite, concluded that the best option was to sculpt scaled-up forelimb bones based on a smaller but well-preserved and purportedly associated right forelimb from BYU locality 681, Cactus Park. Specific elements used were as follows: the humerus BYU 681/4742, the radius BYU 681/4726, and the ulna BYU 681/4708 (Tschopp et al. 2019:33). Wilhite (2003:33) had assigned all three bones to *Diplodocus*, but Bonnan (2007:1111) listed the humerus BYU 681/4742 as belonging to *Camarasaurus*. Ray Willhite (pers. comm., 2024) confirms that the humerus “is part of a partial skeleton of a *Diplodocus* and lacks medially bowed body and medially offset head characteristic of *Camarasaurus*”.

The BYU humerus, radius and ulna respectively measure 61, 47 and 48 in length (Scheetz 2006). By contrast the right humerus of CM 662, from which the original mount’s right forelimb had been sculpted, measures 936 mm (McIntosh 2005a:68). The BYU animal, then, is less than two thirds the size of the previous forelimb provider. This is much too small an individual for casts of its bones to have been incorporated directly into the Carnegie *Diplodocus* mount, hence the scaling of the sculptures.

unit?
~~BYU~~

Caudal vertebrae

It has been generally assumed that all the caudal vertebrae in the Carnegie *Diplodocus* mount are original fossils. In truth, the situation is more complex. The anteriormost 12 caudals are from the holotype, CM 84, and all are real fossils. But the remainder of the tail includes or has included several replicas composed of plaster, plastic, and even wood.

As noted above, Holland (1906:254) explained that in the London replica, Ca13–31 and Ca33–36 were cast from CM 94, and Ca32 and Ca37–73 were cast from CM 307. It is natural to assume that the corresponding real fossils were used in the Carnegie mount, but for numerous complex reasons discussed below, this cannot be so.

Regarding CM 94, Hatcher (1901:4) listed among its bones 20 caudals and 11 vertebrae that were not at that point sufficiently prepared to be identified. He also noted that the caudal “sequence” was found disarticulated, and that the elements cataloged under this specimen number “doubtless pertain to two or more individuals” (Hatcher 1901:34). ~~One~~ ⁰ of the 11 unprepared vertebrae, one (field no. 5) was subsequently identified as a cervical, but the other ten are probably all caudals (McIntosh 2005b). This gives us a total of at most 30 caudals from this specimen, which is in accord with Hatcher’s (1901:34) assessment of “between twenty and thirty other caudals”. (How can we explain the multiple individuals Hatcher alluded to? No information survives to our knowledge. We might speculate that some of the interloper elements were actually caudals of CM 84, but were that so then Hatcher would likely have raised the possibility.)

However, as noted above, McIntosh (1981:20) provided a caudal count of 39 for CM 94. Where can this number have come from? When McIntosh was studying the Carnegie Museum collection in

analyzed the individual elements, and Scott Lucas sent a list of nine plaster caudals: those in positions 13–16, 31, 32, and 33–35 — which is compatible with the two fused pairs being real bone. Even this list cannot be straightforwardly interpreted, however, as it contains one too many caudals in the range 13–36, including two that are both numbered 32 — it is the more anterior of these two “32nd caudals” that is listed as plaster. It may not be coincidentally that Ca32 is the only vertebra in the Ca13–36 sequence that is listed by Holland (1906:254) as having come from CM 307. It is possible that first of the two “32nd caudals” in Scott Lucas’s list is the real anteriormost preserved caudal of the sequence from CM 307, and the second is a cast of a CM 94 vertebra. While it remains possible, then, that the three plaster caudals numbered 33–35 in the list are really those in the designated positions, they are more likely those in positions 34–36. Since the list also mentions a number 36 (i.e., the 37th in sequence) that is real bone, this may indicate that one more CM 94 caudal was incorporated into the mount than Holland (1906:254) had indicated.

It might be expected that numerous CM 94 caudals, conserved and stabilized, would have been incorporated into the 2007 remount in place of plaster casts. However, a database note on this remounting located by one of us (Henrici) says “One caudal added from CM 94.” No records have been found indicating which caudal this was, nor why only one was used. At any rate, it is likely that the number of CM 94 caudal plaster casts remaining in the mount is eight.

The situation regarding CM 307 is similarly complex. McIntosh (1981:20) credits this specimen as having supplied “distal caudals,” and Curtice (1996:73) states “These [CM 307] caudals were used to complete the mount of CM 84, occupying position 32 and 37–73 inclusive” — a total of 38 mid-to-posterior caudals — echoing Holland (1906:254). But there are multiple reasons to believe that much

More recently, one of us (Henrici, pers. obs., 2022) found a “specimen removed” tag in the drawer labeled CM 307 in the museum’s collection area, indicating that at least some elements of the specimen were removed from this drawer for loan to PFP on 20 November 2006. Correspondence between another of us (Matthew Lamanna) and Scott Lucas confirms that, in November 2006, Carnegie staff sent an unspecified number of caudal vertebrae from CM 94 and CM 307 to the PFP studio – most likely the single vertebra of CM 94 referred to in the database note cited above and the 18 of CM 307 that had been photographed by Harris in ca. 2003. No CM 307 caudals remain in the drawer today, presumably because they were all incorporated into the mount. (It would have been natural to return the real caudals to the tail when it was reposed in its present elevated posture, far out of reach of opportunistic museum visitors.)

There are no wooden caudals remaining in the mount today (Henrici and Church, pers. obs., 2023), so as well as reintegrating the 18 fossil caudals photographed by Harris, it is likely that the PFP crew constructed four additional replicas to replace the wooden ones that had themselves replaced those that had been stolen.

Adding to the confusion, the database note located by Henrici and mentioned above continues “Caudals 37–73 were casts in original mount and replaced with caudals from CM 307.” (Note that the stated range encompasses all the CM 307-derived caudals in the mount apart from Ca32.) This note is at least partly incorrect, however. Photographs of caudals 37–46 supplied by Phil Fraley, which were taken after they were removed from the old mount for the remounting process (Figure 19), clearly show that these elements were real bone and not casts. (Incidentally, Holland’s [1906:plate XXIX] illustrations of these caudals do not closely resemble the actual fossils.) Perhaps the phrase “original

FIGURE CAPTIONS

Figure 1. The real mounted skeleton of *Diplodocus carnegii* as it is today: the original fossil material mounted in the *Dinosaurs in Their Time* exhibition at Carnegie Museum of Natural History. Anterior half of skeleton in left lateral view, with *Homo sapiens* Michael P. Taylor for scale. Photograph by Mathew J. Wedel.

Figure 2. Six of the key players in the story of the Carnegie *Diplodocus* and its casts. **A.** Andrew Carnegie, the millionaire industrialist and philanthropist who funded the creation of the Carnegie Museum and after whom it is named; **B.** William J. Holland, second director of the Carnegie Museum, whom Carnegie tasked with sourcing a giant dinosaur to exhibit and who later published extensively on *Diplodocus*; **C.** Olaf A. Peterson, who led the excavation of the paratype specimen CM 94. (See Figure 5 for those who excavated the holotype specimen CM 84.); **D.** Arthur S. Coggeshall, who was the lead preparator of the *Diplodocus* fossils and supervised the subsequent mounting of both the original material and the casts; **E.** John B. Hatcher, who wrote the classic 1901 monograph describing the new species *Diplodocus carnegii* based on CM 84 and CM 94; **F.** Serafino Agostini, leader of the Italian crew that made the plaster molds and sculpted some of the elements that these were taken from.

Figure 3. Newspaper article “The Dinosaur of Wyoming”, from the *New York Post* of 1 December 1898 (Anonymous 1898a), with Andrew Carnegie’s handwritten note to William J. Holland: “My Lord – Cant you buy this for Pittsburgh – try. Wyoming State University isn’t rich – get an offer – hurry AC”. (The “C” at the very end has a double loop characteristic of Carnegie when signing his own name.)

Figure 15. The present skull on the mounted skeleton of *Diplodocus carnegii* at the Carnegie Museum, in right anterolateral view. This is believed to be a cast of the complete and largely undistorted diplodocine cranium and mandible CM 11161. Note the realistic bone texture, including damage, especially on the mandible. Photograph by Joshua Franzos, used with permission. *Nothing about sclerotic ring?*

Figure 16. The mounted skeleton of *Diplodocus carnegii* at the Carnegie Museum in left anterolateral view, by Melinda McNaugher/Carnegie Museum of Natural History. This photograph was taken some time between 1985, when McNaugher became the exhibit photographer, and 1999. It cannot date from later than 1999 because the original replica forefeet are still in position, with their splayed metacarpals and unguals on digits 1–3. Note that the neck support had by this time been changed since earlier photographs (e.g., Figure 14A–B), now suspended from the ceiling rather than supported from below by a tripartite pole.

Figure 17. Right forefeet of the Carnegie *Diplodocus* and its casts, all in approximately anterior view.

A. The feet as originally mounted in 1905 (in the London cast), 1907 (in the first iteration of the Carnegie Museum original-material mount), and subsequent casts, as supervised by Hatcher and Holland and executed by Coggeshall. This photograph shows the right forefoot of the Paris mount, which is unchanged since its original mounting. This forefoot material, sculpted from the camarasaurid specimen AMNH 965, has elongate metacarpals splayed in a semi-plantigrade posture, with multiple phalanges on each of the three medial digit and large unguals on digits I, II, and III. Photograph by Vincent Renéleau (MNHN); **B.** The right forefoot of the Berlin mount, as remounted in 2006 by Research Casting International, supervised by Kristian Remes. This consists