Reconstructing an Icon: Historical Significance of the Peabody’s Mounted Skeleton of *Stegosaurus* and the Changes Necessary to Make It Correct Anatomically

by

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Abstract:

The iconic dinosaur *Stegosaurus* was named by Othniel Charles Marsh of Yale University in 1877 from several caudal elements and a large dermal plate of *Stegosaurus armatus* Yale Peabody Museum specimen 1850 found in the Late Jurassic Morrison Formation near Morrison, Colorado, USA (Marsh 1887). In 1910, the Yale Peabody Museum of Natural History was the first institution to construct a mounted composite skeleton of *Stegosaurus*, and there have been only two major changes to the mount in the last century (Lull 1910). The mount was originally intended to depict *S. ungulatus* (Marsh 1879), but because the validity of this species is subject to debate, and because the validity of the type species of the genus (*S. armatus*) has also been called into question, this classification is no longer informative (Galton, 2010).

As part of the pending Great Hall Renovation project, the Yale Peabody Museum plans to remount its composite skeleton of *Stegosaurus*. The intention is to reconfigure the skeleton posed in a defensive posture swinging its tail at an attacking juvenile *Allosaurus* (Dingus 2011). My thesis focuses on ascertaining what details need to be adjusted in order to ensure the accuracy of the remounted stegosaur. Based on a thorough review of the literature and on measurements and observations made of specimens in museums in Denver, Switzerland, and here at Yale, I have determined that the following changes will be necessary to make the current mount correct anatomically when it is remounted in the renovated Great Hall: Replace the left femur with either Yale Peabody Museum specimen 1856 or 1858 and sculpt a matching right femur of similar size based on the left; Arrange the small anterior nuchal dermal plates in an alternating arrangement; Remove two pairs of anterior spikes from the tail; Add one cervical vertebra; Replace the current skull, a cast of United States National Museum specimen 4934, with a slightly larger skull sculpted from it.

Introduction:

Stegosaurus is a genus of ornithiscian dinosaur from the North American West that is easily recognized by its parasagittal rows of dermal plates, tail spikes, tiny head, and unusual quadrupedal stance in which the hind limbs are greatly elongated compared to the forelimbs. The stratigraphic occurrence of the type species *Stegosaurus armatus* is in the Late Jurassic Morrison Formation of Morrison, Colorado, USA (Marsh 1887). The scientific history of *Stegosaurus* is deeply tied to the Yale Peabody Museum, where the holotype *Stegosaurus armatus* Yale Peabody Museum specimen 1850 resides (Marsh 1877). Although its iconic silhouette may seem to remain constant in the public eye, the reconstructed form of this dinosaur has been changing with the input of new data over the past 130 years since its discovery. Significant modifications have been made to paleontologists' ideas of stegosaurian anatomy and phylogeny since O.C. Marsh's naming of *S. armatus* in 1877. From Marsh's original conception of *Stegosaurus* as an aquatic reptile whose body was "…protected by large bony dermal plates, somewhat like those of *Atlantochelys* (*Protostega*)," through his later reconstructions of *Stegosaurus* which move towards the modern interpretations, this dinosaur has undergone several alterations in anatomy (Marsh 1877; Gilmore 1914). One reason that much of this change remains obscure to the public is that the mounts displayed in museums are often outdated, as it is difficult and expensive to keep these physical representations up to speed with advances made by researchers on a yearly basis. This is the case for the Yale Peabody Museum's mounted *Stegosaurus*, which has been granted the chance for a facelift by the forthcoming Great Hall Renovation Project.

> "There has recently been mounted at Yale University an almost perfect example of the armored dinosaur *Stegosaurus,* in many respects the most grotesque reptile the world ever saw. The interest lies not only in this, but in the fact that, while well known in literature owing to the masterly restoration upon paper by Professor Othniel C. Marsh, this reconstruction constitutes the first actual assembling of the bones in their proper relationships with, as usual, a somewhat different result from the generally accepted condition of the animal." R.S. Lull (1910a).

The Yale Peabody Museum's mount of *Stegosaurus ungulatus* based on the reconstructions of O.C. Marsh was erected in the old Peabody building in 1910 (Lull 1910) (Fig.1). R.S. Lull's (1910a) commentary above on the Peabody's newly mounted *Stegosaurus* skeleton gives valuable historical context to the mount*,* which he would be responsible for modifying 14 years later when it was moved to the Great Hall in the current Peabody building after the 1917 demolition of the old facilities. In the early 1920s Lull changed the configuration of the parasagittal dermal plates from a double paired row to a double alternating row to reflect changing views on their arrangement based on fossil evidence of alternating plates from United States National Museum specimen 4934 as well as Gilmore's reasoning concerning the lack of matching pairs of plates (Gilmore 1914) (Fig. 2). The only other major change made to the mount since that time was just prior to Feb 1991 when the original reconstructed skull of Yale Peabody Museum specimen 1853 was removed and replaced with a cast of the skull of United States National Museum specimen 4934 (Galton 2001).

The history of this mount is particularly significant in light of the current plans for its remounting as part of the Great Hall renovation project which the Peabody has undertaken over the next several years. The mount will be one of the centerpieces of the new Great Hall displays, and will be featured in a dynamic pose, swinging its spiked tail at an attacking juvenile *Allosaurus* while the mounted *Apatosaurus* looks on warily (Dingus 2011). The artist Jason Brougham has been commissioned to realize this scene. According to the narrative walk-through of the new Great Hall, this intense combat scene was chosen to highlight the shift in attitudes concerning dinosaur activity levels, from portraying them as slow-moving and ungainly to acknowledging that they were likely active and capable of agility (Dingus 2011). Every effort will be made to render this scene in the utmost realistic fidelity and to make the new mounts as scientifically accurate as possible. Looking forward to assess what changes need to be made in order to bring the Yale Peabody Museum mount up to modern standards, it is important to keep in mind the original motivations for the placement of every bone in each version of the Peabody's *Stegosaurus*. How these anatomical relationships have changed can be used as a proxy to track the changes in scientific knowledge of the genus that have taken place from its original discovery through the current debates on its more enigmatic nuances.

Based on comparisons to other stegosaurs, including Yale Peabody Museum specimens, as well as specimens from the Denver Museum of Nature and Science, the United States National Museum, and the Sauriermuseum Aathal, it is evident that the current Peabody mount has certain characteristics that do not conform to the norms of the clade, and must therefore be modified in order to present a correct modern interpretation of this dinosaur. Most of the proposed changes are subtle, such as the addition and removal of vertebrae or the adjustment of the relative proportions of the limbs by shortening the femora, but the most visually striking change will be the removal of two of the current four pairs of tail spikes. Much progress has been made towards a realistic depiction of *Stegosaurus* since Marsh's initial idea of the dinosaur as an aquatic animal with a plated carapace-like back (Marsh 1877). The imminent revision will take the current mount from an outdated portrayal of the "mythical" eight-spiked *Stegosaurus* to a modern interpretation representing the advances made through recent research on this dinosaur (Carpenter and Galton 2001).

The aims of the current study are to provide a historically accurate account of the construction and subsequent modifications to the Yale Peabody Museum *Stegosaurus* mount, including an assessment of the composite nature of the skeleton and the changes made to the plate arrangement by R.S. Lull in 1924 from two rows of paired plates to two rows of alternating plates, to determine which features of the current mount (such as the limb proportions and the numbers of plates, spikes, and vertebrae) are inaccurate and in need of correction, and to supply the Peabody staff and its hired artist with the exact specifications and dimensions with which to eventually remount the composite skeleton.

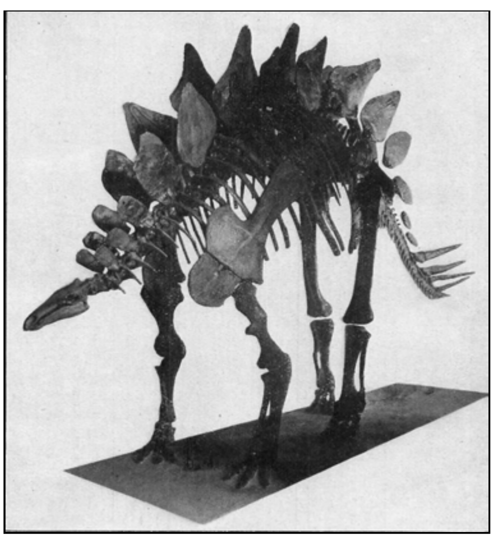


Fig. 1 Oblique view photograph of first (1910) mounted skeleton of *Stegosaurus ungulatus* at the Yale Peabody Museum (Gilmore 1914: pl. 36).

Fig. 2 Photograph of Current YPM Mount

Institutional abbreviations:

AMNH, American Museum of Natural History, New York, New York

DMNS, Denver Museum of Nature and Science; Denver, Colorado

HMNH, Hayashibara Museum of Natural History; Okayama, Japan

MNHM, Morrison Natural History Museum; Morrison, Colorado

SMA, Sauriermuseum Aathal; Aathal, Switzerland

USNM, United States National Museum; Washington, D.C.

YPM, Yale Peabody Museum; New Haven, Connecticut

Anatomical abbreviations:

L: Left
R: Right
RF: Right forelimb
LF: Left Forelimb
RH: Right Hind limb
LH: Left Hind limb

Background:

In order to address the past and future installations in the Peabody's Great Hall, it is useful to define and differentiate between certain museum terms which are used frequently in this study. The term "reconstruction" refers to an attempt to assemble an anatomically correct skeleton as either a three-dimensional mount or a two-dimensional image (Johnson and Ostrom 1995). A "restoration", in contrast, is a fleshed-out artistic representation of how the animal would have appeared in life, and may also take the form of a three dimensional model or an image (Johnson and Ostrom 1995). According to these definitions, the mounted skeletons in the Great Hall are considered reconstructions, whereas the Peabody's *Torosaurus* sculpture and the images of the animals in "The Age of Reptiles" mural are restorations. Like the current mount, the new mount of *Stegosaurus* will feature only skeletal elements, and thus will be referred to as a reconstruction.

Figures 3-6 depict several historic restorations and reconstructions of *Stegosaurus* as envisioned by various paleontologists and artists which provide insight into the past perceptions of this dinosaur. Fig. 3 is a restoration by artist Frank Bond of Marsh's original interpretation of the dermal plates forming a carapace-like covering on the back of the dinosaur. This plate arrangement reflects Marsh's earliest idea of *Stegosaurus* as a creature with chelonian affinities (Marsh 1877). Given Bond's early depiction of the form and function of the dermal armor, it is easier to understand the origin of the name "roofed lizard" than from subsequent and more accurate reconstructions. This initial idea arose from early finds of isolated or fragmented plates, and was subsequently adjusted when intact plates were found in association with less fragmentary findings (Gilmore 1914). Bond's restoration also reflects Marsh's more enduring idea of its supposed bipedality, which Marsh reconsidered sometime between 1880 and 1891 (Marsh 1880; 1891). Citing the "great disproportion in length between the fore and hind limbs, greater probably than in any known Dinosaur," Marsh (1880) initially reasoned that when not in its primary aquatic habitat, *Stegosaurus'* main mode of locomotion was bipedal.

By 1891, Marsh had drastically revised his interpretation of the dermal armor from his initial conceptions, and created a reconstruction (Fig. 4) that began to resemble the modern interpretation of *Stegosaurus* more closely. This reconstruction of *S. ungulatus* shows a single row of 12 dermal plates arranged along the dorsal midline, and four pairs of tail spikes which Marsh describes as diagnostic for *S. ungulatus*. He also mentions that there were four "flat spines" which were not included in the reconstruction because of doubts as to their position (Marsh 1891). Abandoning his original idea of bipedality, Marsh (1891, 1896) describes *Stegosaurus* as a slow-moving quadruped, but adds that the longer hind limbs and powerful tail indicate that the animal could have easily supported itself in a tripodal stance. Marsh's 1891 skeletal reconstruction diagram was based on the original type specimens of *S. ungulatus* YPM 1853 and YPM 1858 found in Reed's Quarry 12 and 11, respectively, from the Morrison Formation of Wyoming (Marsh 1891). In 1887, Marsh divorced the two co-types and changed YPM 1858 to the type specimen of *S. duplex* (Marsh 1887). The species *S. duplex* was later recombined with *S. ungulatus* by Lull in his 1910 assessment, citing lack of diagnosable difference between the two specimens (Lull 1910). Marsh's 1891 reconstruction diagram was an amalgamation of different individuals with shifting species determinations. This laid the framework for Marsh's 1910 reconstruction of S. *ungulatus,* which is also composed of several different specimens and individuals.

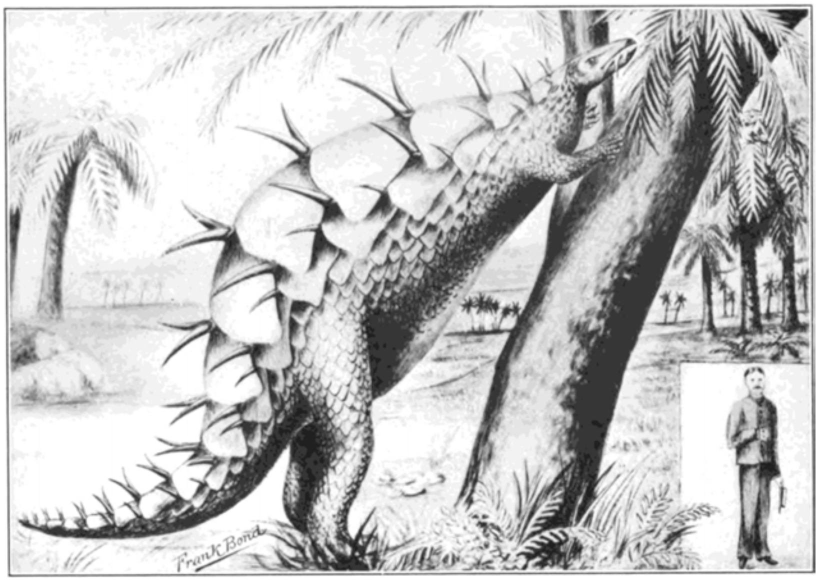


Fig. 3 Early restoration of the "roofed-lizard" with carapace-like covering of dermal armor and spikes by artist Frank Bond. "Restorations of *Stegosaurus ungulatus*." (Pl. 33, Gilmore, 1914)

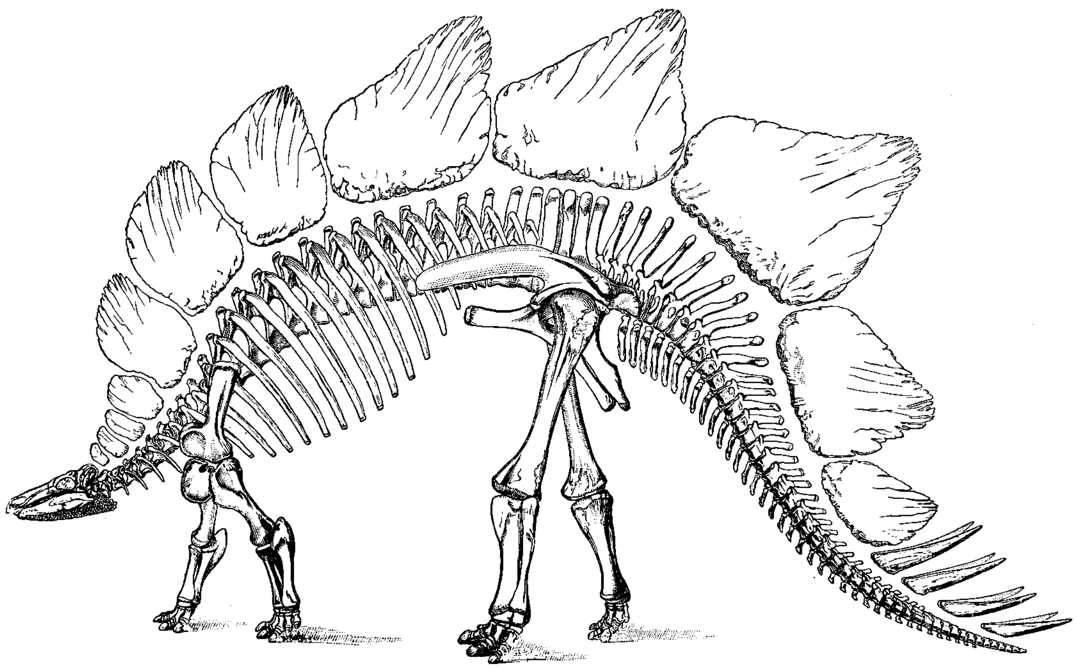
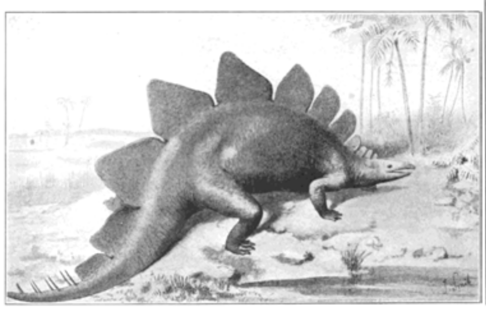


FIG. 1. Restoration of *Stegosaurus ungulatus*. After Marsh. 1/30 natural size.

Fig. 4 Illustration originally from O. C. Marsh. 1896. (Lull 1910: fig 1) after (Marsh 1896).

The debate over the arrangement of the dermal plates and spikes of *Stegosaurus* is an issue that has significantly affected the way this dinosaur has been reconstructed over the years. After Marsh abandoned his initial idea of the plates forming a carapace-like covering over the entire dorsal surface (Fig. 3), he depicted the plates in a single non-overlapping row along the dorsal midline (Marsh, 1891) (Fig 4). A restoration of *S. ungulatus* shows what this incarnation of the dinosaur would have looked like emerging from its aquatic habitat, which Marsh also originally hypothesized (Fig. 5). The switch to a paired double row of plates was later advocated by Lull (1910). This paired double row arrangement was used in the original 1910 YPM mount, and it is portrayed in Charles R. Knight's 1912 restoration, which also features the enduring 8-spiked tail (Gilmore 1914) (Fig.6). This reconstruction was published two years prior to Gilmore's (1914) exposition of the armor of *Stegosaurus* in his seminal monograph "Osteology of the armored Dinosauria in the United States National Museum". Based on new evidence of overlapping plates from the nearly complete, articulated individual USNM 4934, the type specimen of *S. stenops*, Gilmore argues that the plates are arranged in two rows of alternating plates on either side of the midline. Gilmore (1914) notes that the plates change in size and shape throughout the series, observing that the posterior nuchal plates gradually increase in height anteroposteriorly and the dorsal plates also increase rapidly in size from front to back before decreasing in size over the caudal region. For most of the plates in the series of a given individual, there is no matching plate of the same dimensions and shape that would fulfill the criterion of symmetry associated with the paired double row hypothesis (Czerkas 1987). The exception to this apparent lack of symmetrical elements is for the small anterior nuchal plates, which are often mounted or depicted as 2-3 pairs in a double row, even on reconstructions and restorations which depict the dorsal plates in an alternating arrangement.



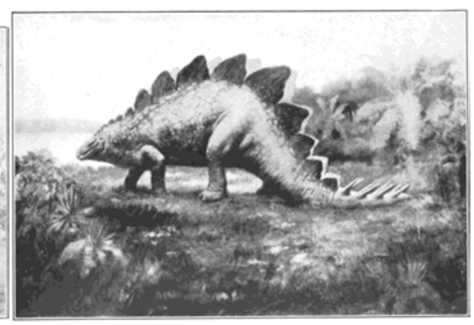


Fig. 5 (Left) Restoration of *Stegosaurus ungulatus*. (Pl. 32, Gilmore, 1914)

Fig. 6 (Right) Charles R. Knight, 1912 Resoration showing 8 tail spikes and 2 paired rows of plates in "Restorations of *Stegosaurus ungulatus*." (Pl. 33, Gilmore, 1914)

In regard to the positioning of the plates along the back, Gilmore (1915:355) states that, "the dermal plates of opposite rows alternated, not paired; that the largest plate of the series, as shown by two individuals found in place, is above the base of the tail, not over the pelvis, that there are not more than 18 in the complete series of flat plates, that the dermal spines number four, based upon the evidence of association in six individuals; that the bases of the plates of opposite rows are comparatively close together on either side of the median line of the back…". In this passage Gilmore (1914, 1915) clearly identifies the plate over the base of the tail as the largest, which indicates that no other plate approached its size closely enough to introduce ambiguity into this designation. The presence of a single largest plate above the base of the tail, instead of two similarly-sized large plates, supports the hypothesis that the plates were arranged in two alternating rows. Gilmore (1915) also points out that by positioning the largest plate over the pelvic region instead of the base of the tail, earlier reconstructions and restorations required an elongate body to accommodate the rest of the anterior plates. This indicates a clear error in the early reconstructions.

While Gilmore (1914) was the first to assert that the paired plate arrangement did not make logical sense unless the mates of many plates were missing, more recent studies by Carpenter (1998) of a nearly complete articulated in situ specimen from Garden Park, Colorado, DMNS 2818 *Stegosaurus stenops* confirm Gilmore's hypothesis. The fossilized plates of DMNS 2818 overlap in a way that suggests that the plates were arranged in two alternating rows with space between them in life (Carpenter 1998). According to Carpenter's (1998) description, the matrix between the plates indicates that each of the alternating rows emerged separately on one side of the midline, as opposed to diverging from a single medial row of plates. Based on measurements of the osteoderms of DMNS 2818 taken as part of an unpublished study by the present author on the arrangement of the dermal armor of *Stegosaurus*, the plates are also unique in shape and size, and do not correspond to matching pairs as would be expected under the paired double row hypothesis (Revan and Brinkman 2009: Table 1, Appendix). This lack of symmetry and telltale taphonomy support Gilmore's original conclusion that the plates of *Stegosaurus* were not arranged in a paired double row, but rather two rows with an alternating pattern. Although there is solid evidence that the plates were not arranged in a double row of paired plates, there have been other arrangements proposed alternatives to the alternating double row hypothesis. Notably, Czerkas (1987) argued for a single row of alternately leaning plates with some overlap of the surfaces of the plates when viewed from the sagittal perspective, but no overlap of their bases. This interpretation was the basis for the plate arrangement of the four well-preserved specimens at the Sauriermuseum Aathal (Siber and Möckli 2009).

When the YPM's *Stegosaurus* was mounted for the first time in 1910, it featured two parasagittal rows of paired plates, 8 tail spikes, and the reconstructed skull of Yale Peabody Museum specimen1853 including the original partial endocast (Lull 1910a; Gilmore 1914) (Fig. 1). Czerkas (1987) notes that when Lull originally mounted the skeletal reconstruction of *S. ungulatus* at the YPM he needed to construct about half of the plates from plaster because their alleged mates were missing. According to Lull (1910a), the specimens which were used in the mount included YPM 1853 and YPM 1858, the original co-types of *S. ungulatus*. Lull considers and dismisses Marsh's decision to re-designate YPM 1858 as the type of the new species *S. duplex* in 1887. In his justification of combining YPM 1853 and YPM 1858 to represent the same species (*S. ungulatus*) he states that "The two individuals embraced in the mount were much alike, as far as one may judge, differing mainly in proportions, No. 1853 being slightly longer and slenderer of limb. The above evidence was submitted to Professors Osborn and Williston and to Messrs. F.A. Lucas and C.W. Gilmore, the question being as to the advisability of combining the specimens in a single mount. The unanimous conclusion was that the validity of the species *S. duplex* was not proven, as the specific characters mentioned could not be contrasted with those of the remaining type of *S. ungulatus*, and that one was abundantly justified in referring the so called type of *S. duplex* back to its former status as a cotype of *S. ungulatus*, and, further, in combining the two supplemental cotypes in a single erection to represent the species and genus as originally described" (Lull 1910a). The difference in proportion of the two main specimens, YPM 1853 and YPM 1858, is explicitly stated by Lull, but the corresponding scientists arrived at the conclusion that this asymmetry would not significantly distort the mount's representation of the species. Because of the qualitative nature of Lull's statement and the method of professional consensus by which the decision was made, it was impossible to precisely state to what degree the elements differed in proportion between specimens until the mount elements were measured in the current study. Lull (1910a) also mentions that the mount contains elements from YPM 1856, a smaller but very complete specimen known as "*Stegosaurus Y"*. This indeterminate specimen was composed of material from several individuals and species, elements of which have since been referred to *Camptosaurus dispar, S. stenops, S. armatus, and Stegosaurus sp.* according to the YPM catalog records. In this respect, Lull's element diagrams and description of the specimens used in the mount do not directly correspond to the diagrams made by Carpenter and Galton in their 2001 study of the YPM mount, or with the observations made in the present study. In addition to YPM 1853 and YPM 1858, the other specimens used in the mount of *Stegosaurus* which Lull did not explicitly mention are YPM 1854 *Stegosaurus sulcatus* and YPM 1859 *Stegosaurus sulcatus*, as well as an uncataloged YPM specimen *Stegosaurus sp.* (Carpenter and Galton 2001). In total, the YPM mount is composed of at least five specimens, and the nature of some of these specimens is such that it is difficult to state with certainty that all of the elements listed under a particular catalog number came from a single individual.

When comparing the archival reconstruction diagrams upon which Lull based the YPM mount and the updated reconstruction diagrams from the analysis of Carpenter and Galton (2001), certain discrepancies are apparent. The main difference is in the attribution of the right forelimb, which is shown to be from the rubble fauna YPM 1856 "Stegosaurus Y" by Lull's diagram, but is differentiated by Carpenter and Galton (2001) to show that the right humerus belongs to YPM 1853, the right manus belongs to YPM 1859, and the ulna, scapula, and coracoid belong to YPM 1854 (the scapula and coracoids being casts of this specimen). The diagrams are otherwise in accord, although further discrepancies arise in the comparison to the mount, which are discussed later in the present study.

Systematics:

The phylogenetic relationships among stegosaurs are obfuscated by several factors that render the systematics of the clade difficult to affirm with certainty. The primary source of ambiguity and confusion is the lack of complete or well-preserved type and referred material for many species, which makes it difficult to score characters and assign these specimens values in a matrix. As new fossils are discovered over the years, more data become available to allay this concern, but many species, particularly the European and Asian stegosaurs, still lack well-preserved representative specimens upon which to base their character matrices. The second main issue which complicates stegosaurian phylogeny arises from convention rather than lack of data, and that is the ambiguous nomenclature applied by different paleontologists when analyzing the clade. How the organisms are grouped is highly dependent on how they are diagnosed and separated into different genera and species, and there is some degree of arbitrariness in what nomenclature paradigm is used. It is important, however, to separate the arbitrary conventional distinctions in naming systems from the real anatomical distinctions between species and genera, for the latter are the distinctions upon which the branches of the phylogeny are based, and they are significant criteria that must be represented in the phylogenetic tree or cladogram.

The first issue of the lack of scoreable fossil material can only be addressed with time as more specimens become available. Already the stegosaurian clade has seen expansion with the naming of new species such as *Huayangosaurus taibaii* (Dong, Tang and Zhou 1982), *Tatisaurus oehleri* (Simmons 1965), *Chialingosaurus kuani* (Young 1959), *Chungkingosaurus jiangbeiensis* (Dong, Zhou and Zhang 1983), *Dravidosaurus blanfordi* (Yadagiri and Ayyasami 1979), *Hesperosaurus mjosi* (Carpenter, Miles, and Cloward 2001), *Monkonosaurus lawulacus* (Zhao 1983), *Tuojiangosaurus multispinus* (Dong, Li, and Zhou 1977), *Wuerhosaurus homheni* and *W. ordosensis* (Dong 1973). In order to address the second issue of the classification of these fossils, it is necessary to assess the validity of the names with respect to the diagnostic characters of the type specimen for each one.

Since the naming of the genus *Stegosaurus*, several species have been recognized, including *S. armatus* (Marsh 1877), *S. ungulatus* (Marsh 1879), *S. affinis* (Marsh 1881), *S. stenops* (Marsh 1887), *S. sulcatus* (Marsh 1887), *S. duplex* (Marsh 1887) and *S. longispinus* (Gilmore 1914). Other members of the stegosaur clade from the Morrison Formation which are currently considered as valid in the literature include *Hypsirhophus discurus* (Cope 1878), *Hypsirhophus seeleyanus* (Cope 1879), *Diracodon laticeps* (Marsh 1881) and *Heseperosaurus mjosi* (Carpenter et al. 2001). *Hesperosaurus mjosi* was subsequently referred to *Stegosaurus mjosi* by Maidment et al. (2008), although the validity of this sister clade was upheld in literature with the naming of the three well-preserved specimens at the Sauriermuseum Aathal (Siber and Möckli 2009), as well as in the studies of Galton (2004, 2010). Currently, there are two different criteria for determining which species should be considered as valid: those put forth by Maidment et al. (2008, 2010), which condense the valid names of the genus *Stegosaurus* (Marsh 1877) to include only *S. armatus* (Marsh 1877), *S. mjosi* (Carpenter et al. 2001), and *S. homheni* (Dong 1973), and those applied by Galton (2004, 2010; Carpenter and Galton 2001), who reviews the type specimens for each of the historically recognized species but does not reject the validity of the currently used names except for *S. armatus*. The rejection of *S.*

armatus by Galton (2010) is based on the lack of diagnostic features of the type YPM 1850.

The type material upon which Marsh named the genus *Stegosaurus* in 1877 consisted of a partial tail and a large dermal plate from the Como Bluff Quarry in the Late Jurassic Morrison Formation of Wyoming (Marsh, 1887). The type of the genus is YPM 1850 *Stegosaurus armatus*, and it is part of a skeleton which is still being prepared at the Morrison Natural History Museum, which currently houses some caudal elements from the type (Carpenter and Galton 2001). The identity of this genus is currently under debate, with a pending proposition to the International Commission on Zoological Nomenclature (ICZN) to change the specimen and species associated with the genus holotype (Galton, 2010). The original and current holotype *Stegosaurus armatus* YPM 1850 (Marsh 1877) has recently been reviewed by Galton (2010). Galton (2010) pronounces the current type a *nomen dubium*, an assessment which this paper supports. Galton (2010) subsequently proposes that the valid name *Stegosaurus stenops,* whose holotype USNM 4934 (Marsh 1887) is a nearly complete articulated skeleton from Garden Park, Colorado, should be designated as the new type species of the genus Stegosaurus (Marsh 1877) in order to conserve the well-established names Stegosauria (Marsh 1877) Stegosauridae Marsh (1880), as well as the classifications of Stegosauroidea and Stegosaurinae. The author considers *S. stenops* USNM 4934 (Marsh 1887) to be a suitable replacement for the original undiagnosable holotype *S. armatus* (Marsh 1877)*,* on the grounds that *S. stenops* USNM 4934 (Marsh 1887) is an articulated skeleton with 17 dermal plates and few missing elements (the distal caudal vertebrae and anterior pair of tail spikes are not present), which features 12 substantiated autapomorphies (Galton, 2010; Gilmore, 1914). According to Galton's (2010) recent analysis, valid Morrison formation stegosaur species include *Hypsirhophus discurus*, *Stegosaurus stenops*, *Stegosaurus ungulatus*, *Diracodon laticeps*, *Stegosaurus sulcatus*, *Stegosaurus longispinus* and *Hesperosaurus mjosi* (?*Stegosaurus mjosi*). The present study concurs with this overall assessment, compared to the assessment of Maidment et al (2008), which invalidates most of the currently used names except for *Stegosaurus armatus*, *Stegosaurus mjosi* (Carpenter et al. 2001), and *Stegosaurus homheni* (Dong 1973). One point upon which the present author agrees from Maidment et al's (2008) phylogenetic study is the inclusion of the species *Hesperosaurus mjosi* within the genus *Stegosaurus,* renaming the species *Stegosaurus mjosi.* Observations of the *Hesperosaurus mjosi (Stegosaurus mjosi)* specimens of the SMA suggest that they do possess distinct morphological traits from other species within *Stegosaurus*, but these variations do not depart from the standard of diagnosis for the genus *Stegosaurus* enough to merit their inclusion in a new genus. A third, more recent description of the valid species from the Morrison formation includes *Hesperosaurus (Stegosaurus) mjosi, Stegosaurus stenops,* and *Stegosaurus ungulatus* (Paul, 2010).

Methodology:

Much of the research for this study took place at the YPM, which houses the mount under examination, the original holotype *Stegosaurus armatus* YPM 1850, as well as a large stock of isolated or disarticulated elements from the original Marsh Quarries. Some conclusions were also drawn from photographs, plates, and descriptions of USNM specimens, particularly the type specimen for *S. stenops* USNM 4934, as well as DMNS specimens. In order to complete the goals of this study, however, it was necessary to compile comparative data from other specimens within the stegosaurian clade that originated from a similar geographic location and time period, and were constrained as individuals based on their taphonomy. A research trip to the Sauriermuseum Aathal (SMA) in Aathal, Switzerland was deemed the best way to gather such data from other individuals within the clade. The SMA houses the most complete and best preserved specimens of stegosaurs known from the Morrison Formation of North America. Unlike most specimens of Morrison stegosaurs, which usually consist of the mixed up fragmentary skeletons of multiple individuals, the best stegosaurs at the SMA were found *in situ* as individual skeletons, which made them ideal for the purposes of this study (Siber and Möckli, 2009).

The SMA specimens considered, which were excavated from the Howe Ranch Site in Wyoming, include the most complete stegosaur currently on display, nicknamed "Sarah" (cf. *Stegosaurus armatus*), as well as several other substantially complete stegosaur specimens including "Victoria" (*Hesperosaurus mjosi*), "Moritz"(cf. *Hesperosaurus mjosi*), and "Lilly" (cf. *Hesperosaurus mjosi*) (Siber and Möckli, 2009). Three of the four specimens at the SMA are currently designated as *Hesperosaurus mjosi*, the relatively new genus named by Carpenter, Miles, and Cloward (2001) based on the type specimen HMNH 001from the Morrison formation of Wyoming. The temporal range of *Hesperosaurus mjosi* spans the Kimmeridgian to the Tithonian of the Jurassic, and the species is found in the Morrison formation at lower stratigraphic levels than the other Morrison stegosaurs (Carpenter, Miles, and Cloward 2001). Based on their phylogenetic study, Maidment et al (2008) regard the genus *Hesperosaurus* as synonymous with *Stegosaurus*, and argue that the specimens currently designated as *Hesperosaurus mjosi* should be renamed as *Stegosaurus mjosi*. Maidment et al (2008:379) cite the presence of six synapomorphies between *Hesperosaurus mjosi* and *Stegosaurus armatus* based on the skull, vertebral column, pectoral girdle and pelvic girdle alone, and describe the anatomical differences between the taxa as "insignificant" compared to their "overwhelming similarity". This is an assessment that the current study supports, and the inclusion of *Hesperosaurus mjosi (Stegosaurus mjosi)* in the genus *Stegosaurus* is justification for the use of the SMA specimens as sources of data.

Several of the goals of this study are based primarily upon the comparison of proportions among different specimens. This necessitates a well-established and consistent methodology for measuring the elements in question. The methods described herein were followed as closely as possible for all of the specimens that were examined, although in some cases, deviations from the original methodology were necessary due to practical considerations. Any departures from the standard are indicated where relevant.

Phase II heavy duty 1000 mm Vernier calipers were used to measure the elements in this study. As a general mode of measuring the elements of mounted skeletons or individual bones, a string was stretched along the length of the desired bone and the corresponding length was measured on the calipers. This method was employed with the SMA stegosaur specimens because of their smaller size and the nature of their display area. The measurements were not taken directly with the calipers because of the unwieldy nature of the large calipers around the delicate mounted bones of the specimens. These circumstances would have made it difficult to maneuver the calipers around the bones to measure them directly, thus secondary a method was deemed more efficient and appropriate to the task at hand. The larger YPM *Stegosaurus ungulatus* mount was measured directly with the calipers, because there is plenty of space to maneuver the instrument around this mount, and the bones were of sufficient size that they could be individually measured without disturbing the mount. The only bones on the YPM mount which were not measured directly with the calipers were the femora, which were too large to be measured by the extension of the caliper jaws. Instead, they were measured in a manner similar to the SMA specimens, using a 5 m Standard tape measure to measure the total femur length, measuring this length against the calipers in two smaller increments which were added together to obtain the total length. It is acknowledged that the secondary measurement techniques may introduce a further level of human errors into the measurements, but the precision and consistence of the instrument were judged to outweigh this risk. The measurements are thus significant to the third decimal place, although the potential for variance in element lengths based on the axis and angle of measurement is acknowledged.

The lengths represented in this paper and in the corresponding figures are measured from the longest longitudinal axis of each bone from proximal to distal end. The bones measured happened to be limb bones, and are thus long in profile, making the length, rather than the width, the significant dimension. Efforts were made to avoid diagonal distortion when choosing the axis of measurement. Some elements showed a notable aberration from normal length and width, either due to diagenetic deformation or pathology of the bone. These cases were noted in the individual specimens, and the dimensions of these particular bones are discounted in calculations of limb ratios when appropriate. When calculating the proportions of the limb elements, the femur was used as the standard for all of the ratios and set equal to 1, because it is the longest element in any of the specimens. The left and right femora were treated separately and used as the standard for their respective sides when possible to minimize the effect of diagenetic distortion on the calculations. The measurement values of the other limb elements were then divided by the length of the femur to obtain the proportions listed in Table 6 (Appendix).

Photographs of the specimens were taken with a Nikon D3100 camera equipped with a Nikon DX AF-S Nikkor 18-55 mm 1:3.5-5.6 G lens. Flash photography was used to compensate for the lack of direct, bright lighting in the specimen display enclosures. Specimens were photographed with a 10 cm scale bar, although the scale is omitted from some long shots of the specimens.

Results and Discussion:

Based on the most recent element inventory of the current YPM mount, as well as measurements obtained from the current YPM mount and the SMA specimens, several factors have been identified which contribute to the inaccuracy of the YPM reconstruction of *Stegosaurus*, and which should be addressed by the upcoming renovation. Some discrepancies arose between the present study's assessment of the elements contained within the current YPM mount and previous assessments of the element affinities (Table 3, Appendix). Carpenter and Galton (2001) do not show the original bone of the L. carpus and metacarpus in their diagram of the current YPM mount, but in their table of elements they do refer to the left carpals as coming from "*Stegosaurus sp.*" YPM uncat. (Figure A, Appendix). Also, the material of the L. carpus and metacarpals seems to come, not from an uncataloged specimen, but from YPM 1859 as it is clearly marked in red paint on the bone. Further discrepancies between the table of elements and visual representation of the mount in the previous assessment of Carpenter and Galton (2001) include the R. radius, which is depicted as plaster in the diagram, but should be shown as original bone of "*Stegosaurus sp.*" YPM uncat., as it is in Lull's original diagram of the mount's bone affinities and in the table of elements (Carpenter and Galton 2001). The phalanges of the R. manus seem to be plaster casts, but are labeled as original bone from an unmarked specimen on the Lull diagram. On the Carpenter and Galton (2001) table of bone affinities, the "Right metacarpals and phalanges" are listed as belonging to *Stegosaurus sulcatus* YPM 1859. Additionally, the right tibia is mostly plaster, but the element diagrams both indicate some original bone from YPM 1853 *Stegosaurus ungulatus* making up the core. This bone is difficult to see, if it indeed exists, and the original bone that allegedly makes up the core of this element is not listed under YPM 1853 on the table of elements (Carpenter and Galton 2001). Lull's archival diagram of the YPM mount, as well as Carpenter and Galton's (2001) recent study both show the posterior part of the skull as being original to YPM 1853, although this has not been the case since the early 1990s when the second major change was made to the mount by replacing this partially sculpted skull with a cast of the skull of USNM 4934.

The dermal plates are also the source of some inconsistencies in numbering and attribution. The pattern of labeling of the plates in Carpenter and Galton (2001) switches in the middle of the series, resulting in a shift of the numbering scheme which renders the diagram unclear. Plate 5, which is a plaster cast, is left off of the diagram, but instead of continuing to designate plate numbers in an alternating fashion following the logical body plan of the specimen, two plates on the left side of the specimen are numbered consecutively. Thus the number of the plaster plate that should be plate 5 is listed as plate 6. In the diagram (Carpenter and Galton 2001) although plate 5 is not shown it is assumed to be a real plate from YPM 1853 due to the double numbering on the left side, and the plaster plate what would have originally been designated as plate 5 on the right side is numbered as plate 6, and shown as plaster on the diagram. This does not reduce the overall accuracy of the diagram, but this shift does not make logical sense, and the plates should be relabeled so that they are numbered in a consistent alternating fashion as they do before and after this single instance of numbering two consecutive plates on the left side. Another major discrepancy between the diagrams and the current mount is that the mount actually features 22 plates, whereas the diagrams depict 21 (Table 4, Appendix). The 22nd plate not depicted in the element diagrams is one of the small posterior caudal plates described as "flat spines" by Marsh (1891) from YPM 1853 *Stegosaurus ungulatus*.

The morphological data from the measurements of the limb elements of the YPM mount were compared to those from the SMA specimens, and the relative proportions of the elements were used to determine which elements of the current YPM mount might be the incorrect size (Table 5, Table 7 Appendix). The results showed that compared to the other specimens, the femora of the current YPM mount are elongated with respect to the other elements. The femora exceed the expected proportions by 0.330-0.200 m, and must therefore be shortened to fall within the range of 1.138-1.008 m. This would cause the proportions of the YPM mount to fall within the range established by the comparative specimens. The difference in femur length is significant enough to have a visible effect on the mount, and should therefore be rectified to ensure the accuracy of the mount. Femora from the YPM collections which fit in this range and may be used as the basis for replacement include YPM 1856 and YPM 1858, which are left femora with lengths of 1.1577 m and 1.175 m respectively (Table 8 Appendix). A matching right femur would need to be sculpted in plaster based on the new proportions.

The fibula and tibia of the current mount are generally within the expected ranges in terms of proportion, but the left hind limb of the YPM mount shows a distortion of the fibula that is undocumented in the previous literature. The fibula was apparently subject to significant diagenetic stresses that warped the bone during fossilization, resulting in an offset of aproximately 20 mm in the middle of the bone and pronounced curvature of the normally straight bone. This distortion does not affect the overall proportions of the hind limb, however, since the main determinant of the length of the distal hind limb is the longer and more robust tibia. There is some degree of damage to the left tibia in the middle of the bone that is partially obscured by the armature. This damage is visible as a small rough, rippled patch in the middle of the bone, in the same plane as the distortion of the fibula. Based on appearance alone, this area the tibia looks like an old bone scar or other pathological damage, but considering the significant diagenetic damage to the adjacent fibula, the author concedes that this damage is likely diagenetic as well. Still, the possibility of pathology is noted based on the textural condition of the bone, and further examination upon the removal of the metal armature is advised. As this damage does not affect the overall length or proportion of the lower hind limb, it is not deemed necessary to look for a replacement. If this damage to the lower left hind limb is purely diagenetic, it may be necessary to modify the narrative of the scene presented in the renovated Great Hall, which refers to the *Stegosaurus* as exhibiting a limb due to a crippling former injury (Dingus, 2011).

The new mount of the Peabody's *Stegosaurus* will be featured in a dynamic defensive posture, swinging its spiked tail to ward off an attacking juvenile *Allosaurus.* There is evidence for such predator-prey interactions between *Stegosaurus* and *Allorsaurus* based on injuries found on *Allosaurus* bones that match the size and shape of

Stegosaurus spikes (Carpenter, Sanders, McWhinney, and Wood 2005). Given the proposed scenario of *Stegosaurus* being mounted in a defensive posture, new data from the study of Mallison (2010) on the body posture and range of motion of *Kentrosaurus aethiopicus* is relevant to the new mount. This study advocates a sprawling defensive posture, on the grounds that the splaying of the forelimbs would confer defensive advantages, such as broadening the support base, increasing stability, allowing the inertially-induced anterior lateral body motions to be countered by elbow extension, and enhancing pivoting capabilities for defensive maneuvers (Mallison, 2010). The positioning of the forelimb elements in the new YPM mount can be adjusted to match the angles proposed by Mallison (2010) for the analogous sprawling defensive stance of *Kentrosaurus aethiopicus*.

The skull currently attached to the Peabody mount is a cast of the skull of USNM 4934. The greatest length of the skull of UNSM 4934 is 0.414 m (Gilmore 1914). From this length and the measurements provided by Gilmore (1914), it can be determined that the ratios of the skull length to the femora (L and R respectively) are 0.410 L and 0.383 R for USNM 4934. Given the current length of the femora of the YPM mount, 1.3388 R and 1.3017 L, the skull is too small compared to the femora of the mount. When the femora are shortened to the lengths proposed in the current study (between 1.138-1.008 m), however, this discrepancy will be less pronounced, and the skull may not need to be enlarged. The proportions of the skull with respect to the other limb elements indicate that it is marginally small for the current mount, but this difference in size may not merit the replacement of the current skull. If the skull were to be replaced, however, a slightly larger skull (on the order of 10-20 mm longer) would need to be sculpted from the current cast.

Other concerns of anatomical accuracy included the accuracy of the elements of the pes and manus. According to Coombs' 1978 analysis of dinosaur cursorial adaptations, the foot of *Stegosaurus* has "modest pedal symmetry" resulting from the loss of the first and fifth digits of the pes, but more advanced cursorial adaptations are otherwise absent from the large herbivore. (Coombs 1978:406, Fig.11) The number of phalanges in the current mount agrees with this description. Coombs (1978) also advocates a graviportal stance for stegosaurs based on the proportions of the forelimb and hind limb elements.

According to the current literature, the average *Stegosaurus* has 10 cervical vertebrae, 16 dorsal vertebrae, a synsacrum consisting of 2 dorsosacrals, 2 sacrals, and 1 caudosacral, and 45 caudal vertebrae (Galton and Upchurch, 2004). This makes for a total vertebral column around 76 vertebrae long (Table 8 Appendix). The current YPM mount has 9 cervicals, 17 dorsals, 5 vertebrae making up the synsacral series, and 46 caudals for a total of 77 vertebrae. This number does not deviate significantly from the norm of the genus. There is a single cervical vertebra that is lacking in the YPM mount compared to the norm for the genus, and adding one posterior cervical would rectify this difference. Still, the length of the neck of the YPM mount compared to the total length of the vertebral column and, consequently, the total body length seems short when compared to the SMA specimens. This is because the three specimens of *Stegosaurus mjosi* on display at the SMA are all mounted with more than 10 vertebrae. "Mortiz" features 2 original cervical vertebrae salvaged from the difficult excavation, and 10 reconstructed vertebrae. "Victoria" was found with 9 cervicals, including the atlas and axis, and 3 more were added as casts to complete the series. "Victoria" has the best-preserved neck of all of the specimens, with 10 articulated cervical vertebrae with a complete skull perched at the end. Two cast vertebrae were added to complete the series near the dorsal end. "Sarah" also has 12 vertebrae total, 6 of which are original. The number of fossil vertebrae found with each of these specimens does not exceed 10, so the elongated necks of the SMA specimens are herein dismissed.

The arrangement and orientation of the plates on the current mount reflects the alternating double row hypothesis which has been supported by fossil evidence (Carpenter 1998). The first two anterior nuchal plates are paired, however, and should be offset to reflect the alternating pattern. The number of the plates is 22, which is higher than the genus standard for *S. stenops*, but it is thought that the plate count for *S. stenops* does not take into account the four "flat spines" (Marsh 1896) at the end of the caudal series just before the spikes. Based on this judgment, the number of plates featured on the mount is reasonable. The tail spikes are, unlike the dorsal dermal elements of *Stegosaurus,* paired, and the overwhelming evidence from in situ finds and total element assays indicates that four spikes total, arranged in two pairs, is the condition that is most plausible for the number of spikes. The eight tail spikes on the current mount are thus twice the confirmed number found with any articulated individual, and the first two pairs of anterior spikes should be removed so that the mount features one pair of larger anterior spikes and one pair of more slender posterior spikes. Regarding the orientation of the tail spikes of *Stegosaurus*, Kenneth Carpenter (1998, 2001) describes the tail spikes as paired structures, two pairs on either side of the tail, projecting posterolaterally in line with the body margin instead of vertically. The angle created between the spike and the tail itself is more acute for the posterior spikes than for the anterior pair (Carpenter, 1998). The bases of the anterior tail spikes are set at a sub-90 degree angle with the tail, and the anterior tail spikes may have also been more deeply set in the tissue, as observed by Gilmore (1914). The studies of Mallison (2010) corroborate with the tail spike orientation and defensive function set forth by Carpenter (1998). The remaining four tail spikes on the YPM mount should be adjusted according to these criteria when they are shifted forward to account for the removal of two of the currently mounted pairs of spikes. The final feature of the dermal armor of *Stegosaurus* which is not currently on display is the patch of throat ossicles. These small round osteoderms that covered the throat are well preserved in situ below the nuchal region of DMNS 2818 (Carpenter 1998), and there are 16 throat ossicles from YPM 1853 in the Peabody collections. This number is only approximately 1/5 of the number of ossicles associated with DMNS 2818 *Stegosaurus stenops*, but the new mount could feature a number of reproduced throat ossicles supplementing the existing amount to replicate the pattern and arrangement seen on DMNS 2818.

Conclusions:

This paper concurs with the assessment of Galton (2010), which pronounces the current holotype *Stegosaurus armatus* Yale Peabody Museum specimen 1850 (Marsh 1877) a *nomen dubium*. Galton (2010) subsequently proposes that the valid name *Stegosaurus stenops,* whose holotype United States National Museum specimen 4934 (Marsh 1887) is a nearly complete articulated skeleton from Garden Park, Colorado, should be designated as the new type species of the genus *Stegosaurus* (Marsh 1877). If the type specimen of the genus is changed to *Stegosaurus stenops* United States National Museum specimen 4934, these measures would result in the re-designation of the Yale Peabody mount as a skeletal reconstruction of *S. stenops*.

The measures which should be taken to make the current Peabody mount of *Stegosaurus* correct anatomically are as follows:

Replace the left femur with either Yale Peabody Museum specimen 1856 or 1858 and sculpt a matching right femur of similar size based on the left;

Arrange the small anterior nuchal dermal plates in an alternating arrangement;

Remove two pairs of anterior spikes from the tail and adjust the position and angle of the remaining four spikes to lie in the posterolateral plane of orientation;

Add partially reproduced area of throat ossicles based on DMNS 2818,

Add one cervical vertebra;

Replace the current skull, a cast of USNM 4934, with a slightly larger skull sculpted from it.

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Appendix:

Figure A. Diagram of YPM Mount reproduced from Carpenter and Galton (2001).

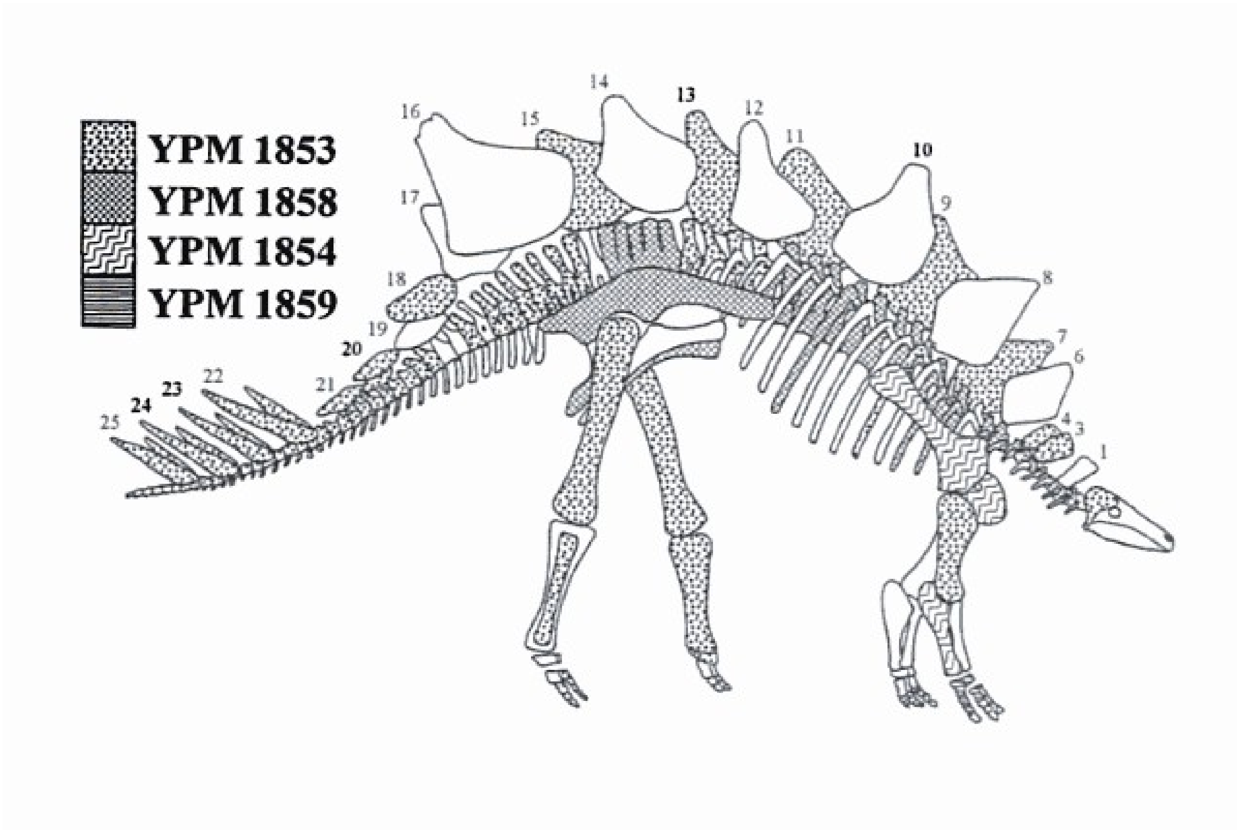

Figure B: SMA "Moritz" *Stegosaurus mjosi*

Figure C: SMA “Victoria” *Stegosaurus mjosi*

Figure D: SMA “Sarah” *Stegosaurus armatus*

Figure D: SMA “Lilly” *Stegosaurus mjosi*

Table 1:
Table of plate dimensions for body region plates B1-B6 and tail region plates C1-C3 from Revan and Brinkman 2009. Unpublished. A Quantitative Assessment of the Arrangement of the Plates of *Stegosaurus.*

Plate/Spike	Base Length= BL (cm)	Max. height =MH(cm)	Max. width =MW (cm)	Posterior apical edge length =PAEL (cm)	Posterior basal edge length =PBEL (cm)
B1	36.8	54.0	51.4	26.0	32.4
B2	~41	57.2	>51	~53	N/A
B3	32.4	>49	54.6	35.0	18.4
B4	46.0	~58	59.7	~46	Obscured
B5	53.0	~61	66.1	59.7	31.1
B6	71.1	108.6	74.3	59.1	24.3
C1	>45.5	64.8	~61	Obscured	obscured
C2	34.3	41.9	39.4	26.7	13.3
C3	24.1	Damaged	Damaged	Damaged	Damaged
S1	18.4	38.7	N/A	N/A	N/A

		*broken			
S2	18.4	32.4 *diseased	N/A	N/A	N/A
S3	13.3	37.5 *broken	N/A	N/A	N/A
S4	12.7	54.6	N/A	N/A	N/A

The following measurements of DMNS 2818 *Stegosaurus stenops* were made:

BL: Base Length; MH: Maximum vertical (dorsoventral) height; MW: Maximum sagittal (anteroposterior) width; ABEL: Anterior basal edge length AAEL: Anterior apical edge length PAEL: Posterior apical edge length, PBEL: Posterior basal edge length (Fig. 2)

Measurements were made using a 10 cm scale bar for smaller elements, accurate to .1 cm, and a 60 inch tape measure, accurate to .1 in., then converted to .1 cm. Measurements are summarized in Table 1.

Table 2:

Element Inventory of Current YPM Mount

Element	**Original Catalog Number**	**Markings**	**Remarks or Discrepancies with Carpenter and Galton (2001)**
L. Manus: Unguals and phalanges digits 1-5	Cast	None	
L. manus carpus	YPM 1859, Stegosaurus sp.	“1859” in red paint	* Carpenter and Galton do not show the original bone in the L. manus wrist in their figure, but do refer to the left carpal as coming from “Stegosaurus sp.” YPM uncat. in their table of bones. Discrepancy btwn. Table and figure? Also, this bone seems to come, not from an uncat. specimen, but from YPM 1859 as it is clearly marked in red paint
L. manus digit 3 metacarpal?	Possibly a real element, marked	Small “M”-like red marking on	Not indicated as real in Carpenter and Galton, but

	as belonging to another specimen in Lull, but ignored as plaster in Carpenter and Galton	the bone, possible indicator of its identity as real bone vs. plaster	may be an original fossil
L. manus digit 2 metacarpal?	Possibly a real element, marked as belonging to another specimen in Lull, but ignored as plaster in Carpenter and Galton	Small red marking on the bone, possible indicator of its identity as real bone vs. plaster	Not indicated as real in Carpenter and Galton, but may be an actually an original fossil
L. ulna	Plaster	Small “x” markings	
L. radius	Plaster		
L. humerus	*Mostly plaster, but the distal base where it contacts the ulna may be original bone, a small region has bone texture and porosity, unlike the plaster making up most of the length of the bone, but no indication of specimen no., and is not referred to in either diagram of bone affinities	Small “x” markings	Possibly has a base of real bone of the distal end? Not referred to by C. & G. or Lull
L. scapula	Plaster	Small “x” markings	
L. coracoid	Plaster	Small “x” markings	
R. Manus:	All unguals and	Edge of a red	Seem to be plaster, but are

Unguals and phalanges digits 1-5	short rectangular distal phalanges appear to be plaster, exceptions are the longer proximal phalanges,which appear to be original bone, especially in digits 2,3,4	rectangle visible on the side of the proximal phalanx of digit 3	labeled as original bone from an unmarked specimen on Lull diagram, and the phalanges are not labeled in the C. & G.diagram, except for possibly 1-2 (resolution makes it difficult to tell) BUT, on the table of bone affinities in C. and G., it says that “Right metacarpals and phalanges” are taken from *Stegosaurus sulcatus* YPM 1859 (Ostrom and McIntosh 1966; pls. 37-41)* Look Up Plates*
R. manus carpus	YPM 1859, *Stegosaurus sulcatus* Original bone	Red indeterminate markings on bone surface, once were numbers, now faded	
R. manus metacarpals	Original bone, but not marked- C. and G. table Identifies them as YPM 1859 *Stegosaurus sulcatus*	No visible/intelligible markings	
R. ulna	YPM 1854, *Stegosaurus sulcatus*	Red paint “1854” on posterior side of bone	
R. radius	YPM uncat.? Original bone, but not numbered- C. & G. table	No visible/intelligible markings	Not shown as orig. bone in C.&G. Diagram, but recorded on their table as belonging to YPM Uncat, *Stegosaurus sp.*
R. humerus	YPM 1853 *Stegosaurus ungulatus*	Accession number in diamond, “/271/” on posterior and anterior side of bone, YPM number “18__” visible on posterior side of bone, but the last 2 numbers are faded from view	
R. scapula	YPM 1854 *Plaster Cast*- but cast from orig. specimen according to	Small “x” markings	

	C.&G.		
R. coracoid	YPM 1854 *Plaster Cast*- but cast from orig. specimen according to C.&G.	Small “x” markings	
L. pes unguals	Plaster	No visible/intelligible markings	
L. pes phalanges- short rectangular phalanges	Plaster?		
L. tibia	YPM 1853 Stegosaurus ungulatus	“1853” Accession number in diamond, “/271/”	
L. fibula	YPM 1853 Stegosaurus ungulatus	“1853” Accession number in diamond, “/271/”	
L. femur	YPM 1853 Stegosaurus ungulatus	“185_”, end of cat. number obscured by armature	
R. pes unguals	Appear to be original bone		
R. pes phalanges- short rectangular phalanges	Appear to be original bone		
R. pes digit 3 long phalanx	Original bone, YPM 1853?	Partially eroded part of a red diamond visible, but no numbers visible	
R. tibia	Mostly plaster, but diagrams both indicate some original bone in core, YPM 1853 Stegosaurus ungulatus, this bone is difficult to see, if it indeed exists	Small “x” marking on distal poserior side of bone	The original bone that allegedly makes up the core of this element is not listed on C. & G.'s table under YPM 1853
R. fibula	YPM 1853 Stegosaurus	“1853” in several places in red paint, Accession number in diamond, “/271/”	

	ungulatus		
R. femur	YPM 1853 Stegosaurus ungulatus	"1853" in red paint, Accession number in diamond, "/271/"	

Table 3:

Dermal Plate Inventory for Current YPM Mount

Plates: Numbered after Carpenter and Galton (2001) diagram anteroposteriorly	Original Catalog Number (or plaster)	Markings	Remarks, Discrepancies with Carpenter and Galton (2001) diagram or table of elements
1 (anteriormost nuchal plate)	Plaster	"x" markings	Mirror image of plate 2, arranged parallel to plate 2 as a pair
2	Plaster	"x" markings	Mirror image of plate 1, arranged parallel to plate 1 as a pair
3	YPM 1853 Stegosaurus ungulatus	"1853"	First plate in series to be offset with respect to the plate across the midline, alternating arrangements starts here
4	YPM 1853 Stegosaurus ungulatus	"1853"	
5 Numbering shift in C. & G., should be corrected	YPM 1853 Stegosaurus ungulatus, tip is plaster	"1853" , accession number /271/ in parallelogram	*Carpenter and Galton are inconsistent in their labeling, resulting in a shift of their numbering scheme (ironically analogous to the frame shift which may have offset the plates) They leave plate 5, which is a plaster cast, off of their diagram, but instead of continuing to designate plate numbers in an alternating fashion following the logical body plan of the specimen, they number 2 plates consecutively on the left side of the specimen, and number the plaster plate that should be plate

			5 as plate 6. Thus in C. &G, plate 5 is not shown on the diagram but assumed to be the real plate from 1853 due to their double numbering on the left side, and the plaster plate what would have originally been designated as plate 5 on the right side is numbered as plate 6, and shown as plaster on the diagram. This does not reduce accuracy of their diagram, but this shift does not make sense, and the plates should be renumbered so that they continue to be numbered in an alternating fashion as they were at the anterior of the skeleton and continue to be after this single instance of numbering two consecutive plates on the same side The top part of this plate is reconstructed in plaster, but most is original bone
6	Plaster	"x" markings	
7	YPM 1853 Stegosaurus ungulatus	"1853" accession number /271/ in parallelogram	
8	Plaster	"x" markings	
9	YPM 1853 Stegosaurus ungulatus	"1853"	
10	Plaster	"x" markings	
11	YPM 1853 Stegosaurus ungulatus	"1853"	
12	Plaster	"x" markings	
13	YPM 1853 Stegosaurus ungulatus	"1853"	
14	Plaster	"x" markings	
15	YPM 1853 Stegosaurus	"1853"	

	ungulatus		
16	Plaster	“x” markings	
17	Plaster	“x” markings	
18	YPM 1853 Stegosaurus ungulatus	“1853”	
19	Plaster	“x” markings	
20	YPM 1853 Stegosaurus ungulatus		
21	YPM 1853 Stegosaurus ungulatus		
22 (last caudal plate)	YPM 1853 Stegosaurus ungulatus	There are **22** plates total, C&G leave one unnumbered	

Table 4:
Table of measurements of current YPM mount, USNM 4934 (Gilmore 1914), and SMA specimens “Victoria”, “Sarah”, and “Moritz”

Specimen	Humerus (m)	Radius (m)	Ulna (including process) (m)	Femur (m)	Fibula (m)	Tibia (m)
YPM Mount	.5778 R	.3989 R	.5614 R	1.3388 R =.9302 + .4086	0.6396 R	.7536 R
YPM Mount	.6107 L	.4107 L	.5500 L	1.3017 L =.9954 + .3063	0.6993 L- warped	.7559 L
UNSM 4934 *S. stenops*	.572 R	.384	.540	1.080 R		
UNSM 4934 *S. stenops*	.530 L			1.010 L		
Sauriermuseum Aathal Stegosaur	.5173 R	0.3926 R	0.4635 R	.9580 R	.4970 R	.5445 R

"Victoria", *Hesperosaurus mjosi*						
Sauriermuseum Aathal Stegosaur "Victoria", *Hesperosaurus mjosi*	.5666 L	0.374 L	0.5200 L	.5138 L- *half of length broken off	.5043 L	.5637 L
Sauriermuseum Aathal Stegosaur "Sarah", cf. *Stegosaurus armatus*	.4616 R	.3280 R	.4147 R	.8688 R	.4700 R	.4962 R
Sauriermuseum Aathal Stegosaur "Sarah", cf. *Stegosaurus armatus*	.4485 L	.3272 L	.4091 L	.8935 L	.4519 L *L. fibula distorted/warped*	.5038 L
Sauriermuseum Aathal Stegosaur "Moritz", cf. *Hesperosaurus mjosi*	.3971 R	.3157 R	.4283 R	.7715 R	.4219 R	.4626 R
Sauriermuseum Aathal Stegosaur "Moritz", cf. *Hesperosaurus mjosi*	.4368 L	.3183 L	.4172 L	.7673 L	Cast L	Cast L

Table 5:
Table of Measurements of Tail Spikes of YPM Mount (Spikes numbered in ascending order anterior to posterior, measured at longest axis)

YPM Mount Spike Pair	Length (m)	
	Left	Right
1 (anterior)	.6280 L	.6304 R

2	.5897 L	.6078 R
3	.6178 L *warped-pathology?	.5112 R
4 (posterior)	.5419 L	.4983 R

Table 6:
Table of Stegosaur Specimen Limb Proportions with respect to the femur length (= 1) (R and L elements treated separately)

Specimen Proportions w/respect to the femur length = 1 (R and L treated separately)	Humerus (m)	Radius (m)	Ulna (including process) (m)	Femur (m)	Fibula (m)	Tibia (m)
YPM Mount	.4316 R	.2980 R	.4193 R	1.0000 R	.4777 R	.5629 R
YPM Mount	.4692 L	.3155 L	.4225 L	1.0000 L	.5372 L *fibula distorted, diagenic	.5807 L
Stegosaur "Victoria", *Hesperosaurus mjosi* Sauriermuseum Aathal	.5400 R	.4098 R	.4838 R	1.0000 R	.5188 R	.5684 R
Stegosaur "Victoria", *Hesperosaurus mjosi* Sauriermuseum Aathal (R femur used in proportions b/c Left femur broken in half)	.5914 L	.3904 L	.5428 L	1.0000 L	.5264 L	.5884 L
Stegosaur "Sarah", cf. *Stegosaurus armatus* Sauriermuseum	.5313 R	.3775 R	.4773 R	1.0000 R	.5410 R	.5711 R

Aathal						
Stegosaur “Sarah”, cf. *Stegosaurus armatus* Sauriermuseum Aathal	.5020 L	.3662 L	.4579 L	1.0000 L	.5058 L	.5639 L
Stegosaur “Moritz”, cf. *Hesperosaurus mjosi* Sauriermuseum Aathal	.5147 R	.4092 R	.5552 R	1.0000 R	.5469 R	.5996 R
Stegosaur “Moritz”, cf. *Hesperosaurus mjosi* Sauriermuseum Aathal	.5693 L	.4148 L	.5437 L	1.0000 L	N/A -Cast	N/A -Cast
Stegosaur “Lilly”, cf. *Hesperosaurus mjosi* Sauriermuseum Aathal proportions from Diagrams/Photos	0.6500	0.4300	0.6200	1.0000	0.6500	0.6800

Table 7:
Table of potentially relevant elements in the YPM collections for replacement of disproportionate femora on the mount

Element	Location	Catalog No.	Length	Notes
Left Femur	9C.9.12a-e	YPM 1856 on tag, YPM 57503 on bone	.8215 L	*S. stenops*, too small
Left Femur	9C.11.6a-f	YPM 1856 and “B” on bone, YPM 1835 on tag	1.1577 L= .5568 (shaft) + . 3039 (head) + . 2970 (distal end)	In 3 pieces, eroded
Femur fragments	9C.12.8a-j	YPM 4835 (?)	fragmented, missing shaft, no photos taken	Proximal and distal ends of femur only, missing shaft,

				eroded
Left femur	9C.12.10 a-c, unlabeled bottom drawer	YPM 1858	1.175= .424 (distal end)+ .751 (head end)	Large femur in 2 parts
R Femur	9C.14.10 a-f	YPM VP 57496	.9696 R	*S. sp.*

Tables 8 and 9:

Published data on number of stegosaur vertebrae (Table 9) and osteoderms (Table 10) found in fossil specimens
Sources: (Czerkas 1987), (Galton 2010), (Galton and Upchurch 2004), (Siber and Möckli 2009).

Table 8:

Genus/ Species	Cervical Vertebrae (Proposed Total)	Dorsal Vertebrae (Proposed Total)	Sacral Vertebrae (Proposed Total)	Caudal Vertebrae (Proposed Total)	Total/Source
Stegosaurus	10	16	Synsacrum consiting of 2 dorsosacrals, 2 sacrals, 1 caudosacral	45	75 (counting the bones of synsacrum as separate vert.s) (Galton, and Upchurch 2004)
YMP Stegosaurus Mount	9	17	5 (4 fused)	46	77
Huayangosaurus	8	17-18	4: 1 dorsosacral, 2 sacrals, 1 caudosacral	35-42	64-72 (Galton, and Upchurch 2004)
Hesperosaurus	13	11	Synsacrum consiting of 2 dorsosacrals, 2 sacrals, 1 caudosacral	45	73 (counting the bones of synsacrum as separate vert.s) (Galton, and Upchurch 2004)
Wuerhosaurus		11			(Galton, and

					Upchurch 2004)
Sauriermuseum Aathal Stegosaur “Victoria”, *Stegosaurus sp.*	9 found	14 found	5 vertebrae	31 found	(Siber and Möckli 2009)
Sauriermuseum Aathal Stegosaur “Sarah”, cf. *Stegosaurus armatus*	6 found	21 found	Sacrum found	24? found	+~3 other bones identified at “small vertebra” (Siber. and Möckli 2009)
Sauriermuseum Aathal Stegosaur “Moritz”, cf. *Hesperosaurus mjosi*	2 found	None found	None found	12 found	(Siber and Möckli 2009)
Sauriermuseum Aathal Stegosaur “Lilly”, cf. *Hesperosaurus mjosi*	10 found	17 found	3-5 sacral vert.s found	36 found	(Siber and Möckli 2009)
S. Stenops				27 found on USNM 4714 (complete tail)	A reevaluation of the plate arrangement on Stegosaurus stenops SA Czerkas - Dinosaurs Past and Present, 1987
S. armatus		2 found		17-19 found	Galton, 2010

Table 9:

Genus/ Species	Nuchal Osteoderms	Dorsal Osteoderms	Sacral Osteoderms	Caudal Osteroderms	Total	Source
S. stenops	Throat ossicles w/ rosette patterns, 9 nuchal		Largest plate over base of tail	2 pairs of tail spikes	17	(Galton, and Upchurch 2004)

	plates,					
Sauriermuseum Aathal Stegosaur “Victoria”, *Stegosaurus sp.*	None found	7 found		4 spikes found	Possibly 18 total, but only 6 or 7 recovered	(Siber and Möckli 2009)
Sauriermuseum Aathal Stegosaur “Sarah”, cf. *Stegosaurus armatus*	6	5	2	5 plates found, 1 missing plate inferred (6 total), 4 spikes found	18 plates found, plate 14 was missing and its position is inferred (19 total?)	(Siber and Möckli 2009)
Sauriermuseum Aathal Stegosaur “Moritz”, cf. *Hesperosaurus mjosi*	None found	6 found	None found	1 partial tail spike found	Incomplete, 7 found	(Siber and Möckli 2009)
Sauriermuseum Aathal Stegosaur “Lilly”, cf. *Hesperosaurus mjosi*		14 found		4 found	18 Found	(Siber and Möckli 2009)
S. Stenops					17 found on USNM 4934	*A reevaluation of the plate arrangement on Stegosaurus stenops* SA Czerkas - Dinosaurs Past and Present,

						1987
S. armatus		1 found				(Galton 2010)