The Scale of Scales: Why the Shift in Dinosaur Scale Size from the Nineteenth to Twentieth Century?

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Abstract

It was less than ten years after Buckland and Mantell described the first dinosaurs that attempts were made to recreate life-like images of these previously unknown creatures. George Scharff (1833), William Buckland (1836), and John Martin (1837) illustrated these initial renditions based on the rudimentary knowledge of the time. A particularly notable feature of these early dinosaur reconstructions is the size of the scales coating their bodies. Without preserved skin impressions, the interpretation of a dinosaur's external appearances was left to the individual artist. Thus, many early dinosaur renditions were covered with large scales, in some cases measuring more than 30 centimeters across. At the time, reconstructions with large scales were likely done to show the saurian nature of these creatures and to ensure that the scales were visible when viewed from a distance.

The image of dinosaurs with large diameter scales is peppered throughout artwork, cartoons, and literature until the end of the 1800's. The few descriptions of dinosaur skin identified from the 19th century do not appear to sway this image, likely because many of those descriptions were in regional publications and unknown by non-scientists of the time. It is not until the early 20th century that we see dinosaur scales shrink in artwork. The works of Charles R. Knight and Rudolph F. Zallinger provide examples of this reevaluation. But what brought about this change? Knight and Zallinger had associations with museums housing large dinosaur collections, including samples of newly discovered skin impressions. This, together with the two artists' extensive studies into living creatures, likely played a part in the observed change in scale size.

Through the remainder of the 20th and into the 21st century, the discovery of skin impressions from a variety of dinosaur families has confirmed that, in general, dinosaur scales were not very large. In conjunction with finding evidence of feathers on various theropods and advances in technology providing insight into coloration, we now see increasingly realistic reconstructions of these creatures. Today's paleoartists have access to information previously unavailable, leading to more accurate portrayals of dinosaurs in many types of popular culture media.

Introduction

Life-like portrayals of dinosaurs have undergone many changes since first being described in 1824. From obligate quadrupeds to animals with a range of locomotion styles. The large sauropods are no longer viewed as slow, lumbering monsters that spent most of their lives in water to buoy their weight. Theropods are now viewed as quick, agile animals that were capable of moving rapidly or hunting in packs. And dinosaurs are no longer seen as unintelligent, a common thought in early literature (Savile, 1901; Doyle, 1912; Taine, 1934).

One specific feature that has changed is how their exteriors are decorated. Early dinosaur illustrations portrayed them as being covered with large scales that may have been visible from hundreds of feet away while current representations show them with smaller scales that may only be visible from a few feet away. William Buckland's 1836 illustration of an Iguanodon is covered with scales measuring almost three feet across and visible from almost 2000 feet away while the Allosaurus from the 1969 film "The Valley of Gwangi" is covered by scales measuring less than 2.5 inches across visible from 130 feet away. Earlier illustrations also have the dinosaurs covered with imbricate scales while recent works have changed to show nodular scales. Frank Bonds 1916 Stegosaurus contains imbricate scales while the Allosaurus in "The Valley of Gwangi" is covered with nodular scales.

The unearthing of preserved skin impressions starting in the 1840's challenged the initial idea that dinosaur scales were both enormous and imbricate. Edward Hitchcock's first described scales from the footprint of a theropod were quite small, likely measuring only a tenth of so of an inch across, and nodular in appearance. Mantell's description of Pelorosaurus scales from 1852 also show a nodular appearance and only measure approximately 0.65 inches across. More recent skin impressions from Chasmosaurus, Triceratops, Krittasaurus, Tyrannosaurids, and sauropods all follow the similar trend of having smaller scales with a nodular appearance.

Are the changes in scale size and type found in paintings and other forms of artwork over the past 200 years linked to the increased number of uncovered skin impressions found throughout the 19th and 20th century? Or are the observed changes due to other factors like the distance to a subject within a painting or choice of media? The overarching goal of this project is to examine if such a connection exists and if those changes may be tied to any newly discovered skin impressions recovered from the fossil record from the same time period.

Examples of Dinosaur Scales in Various Forms of Media

Figure 1 - Scharf, George Johann, 1788-1860. Scharf, George 1788-1860 :Reptiles restored, the remains of which are to be found in a fossil state in Tilgate Forest, Sussex / G. Scharf del 1833. This served as a sketch for a picture 3 yards long. Iguanodon, calculated from the remains to have been 100 feet long; Monitor; Megalosaurus; Plesosaurus.. Mantell, Gideon Algernon 1790-1852 Country of the Iguanodon. Ca 1830 to ca 1850.. Ref: E-330-f-001. Alexander Turnbull Library, Wellington, New Zealand. /records/22600717

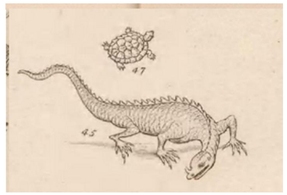


Figure 2 - 1836 - Iguanodon by William Buckland – This initial drawing was a small, 3-inch drawing included in Bucklands book "Geology and Mineralogy Considered with Reference to Natural Theology". The scales are depicted as imbricate and measure tens of inches across (Buckland, 1836)

Figure 3 - 1837 - "The Country of the Iguanodon" by John Martin – The scales of the Iguanodon are more nodular in appearance while those of the Megalosaurus appear overlapping or imbricate.

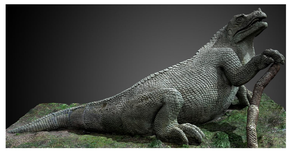


Figure 4 - 1854 - The Iguanodon from the Crystal Palace Dinosaurs. This life size reconstruction by Benjamin Waterhouse Hawkins includes nodular scales measuring several inches across. The image (along with Figures 14 - 16) are screen-captures from the site https://sketchfab.com/historicengland/collections/crystal-palace-dinosaurs-5cc3ed7d0d2e48c0a3edb0f656a970fd, which provides three dimensional models of all the prehistoric creatures from the Crystal Palace display.

Figure 5 - 1914 - Stegosaurus interpretation as illustrated by Frank Bond in Gilmores "Osteology of the Armored Dinosaurs". It was unclear at the time how the plates were configured so Bond drew them lying down with the scales aligned (Gilmore, 1914).

Figure 6 - 1928 - Iguanodon by Gerhard Heilmann (https://www.reddit.com/r/Dinosaurs/comments/16jlrr7/retrovintage_iguanodon_by_gerhard_heilmann/?rdt=40564). Accessed March 1, 2025.

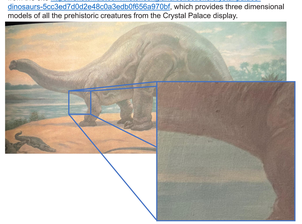


Figure 7 - 1926-1930 - Apatosaurus (Brontosaurus) from the Chicago Field Museum. Close examination reveals texturing though this was due to technique and not an attempt to include details of the skin.

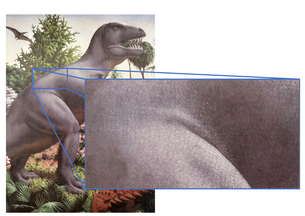


Figure 8 - 1947 - The Tyrannosaurus in Rudulph Zalinger's "The Age of Reptiles". Enlarged area shows details of the skin.

Figure 9 - 1969 - The Allosaurus featured in the film "The Valley of Gwangi", animated by Ray Harryhausen (O'Connoly, 1969)

Examples of Preserved Dinosaur Scales

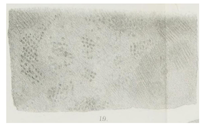


Figure 10 - 1841 - Edward Hitchcock's drawing of the first described dinosaur skin print. It was initially thought to be a large bird since the concept of the dinosaur had yet to be described (Hitchcock, 1841)

Figure 11 - 2024 - Picture of the skin impression of Chasmosaurus. From Yale Peabody Museum.

Figure 12 - AMNH #5360 - Skin Impression of Corythosaurus. Image provided by the staff of the Dept. of Vertebrate Paleontology at the American Museum of Natural History

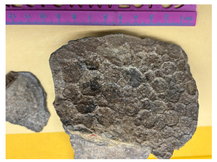


Figure 13 - Kritosaurus skin impression – YPM-PU 16969

Methods

The measurements for each painting or skin impression were found using the program ImageMeter. This program allows one to establish a base measure and then zoom in on individual elements of a painting or image to determine various dimensions. For each painting or skin impression, three measures were taken; scale length, scale perimeter, and scale area.

Sizes within images of actual skin impressions were determined by an established sized object within the image, such as a ruler, a centimeter scale, or information provided in the associated literature. Lengths in paintings or other media proved to be a bit more challenging and required a bit of creativity. For example, the earliest descriptions of Iguanodon stated that the dinosaur was approximately 100 feet long. A surviving preliminary painting of George Scharff's 1833 painting "Reptiles Restored" has this measure written within the margin and within Owen's 1842 text "Report on British Fossil Reptiles, Part II" (Dean, 1999) he notes that previous estimates of Iguanodon ranged close to 100 feet in length, though he himself updates that estimation to the creature being closer to 30 feet in length. Some images, such as the Stegosaurus drawn by Gilmore in 1914 or the Allosaurus from 1969 movie "The Valley of Gwangi" contain an image of a person standing next to the dinosaur. Using an average male human height of 1.8 meters or 70 inches, a value could be assigned for the base measurement. The precise length of the Crystal Palace dinosaurs is not known but rudimentary measures, supplied by Dr. Mark Witton, were used to establish a scale for the three dinosaur sculptures at Crystal Palace Park.

Once the distance scale was established for an image, I zoomed in to identify complete epidermal scales (those that had a distinct boundary surrounding the scale) to be measured. Because details vary amongst images, some pictures contained few scales (i.e. the sauropod skin impression scales from Foster and Hunt-Foster (2011) only showed 5 complete scales) while others contained hundreds of scales (i.e. the Crystal Palace Dinosaurs). I used an average of 15 scales from each preserved skin impression and 24 scales from each of the different forms of media. Once each scale was identified and numbered, three measures were taken; the length, the perimeter, and the area of each scale.

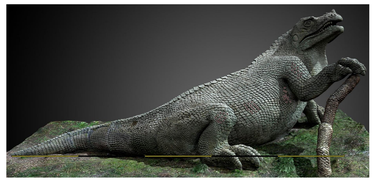


Figure 14 – Iguanodon from the Crystal Palace Dinosaurs. Scale bar is 10 meters in length based on an estimate provided by Mark Witton (Pers. Comm)

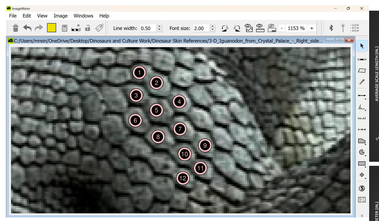


Figure 15 – A few of the numerous scales from the Crystal Palace Dinosaurs used to determine average scales sizes.

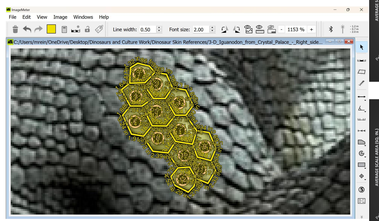


Figure 16 – Scale dimensions of each scale as measured in the program ImageMeter®.

Results

A total of twelve media sources and eight fossilized skin impressions were examined. The media covered a range of types, including paintings, sculptures, print illustrations, and movies. The skin impressions examined encompassed sauropods, theropods, ceratopsids, and ornithischians.

Three, two-tailed T-tests were run to test the hypothesis that dinosaur scale size in media have changed through time as more fossilized skin impressions were recovered (H_0 = Dinosaur scales in paintings and other media do not change as the number of discovered skin impressions increased through time). Three dimensions were measured and tested; scale width/length, scale area, and scale perimeter. Of the three tests run, none proved to be significant (Width = 0.958104, Area = 0.995, Perimeter = 0.729371), indicating that the discovery of new fossilized skin prints had no measurable impact on how artists have illustrated dinosaurs through time.

Genus	Year Described	Avg. Scale Width (in.)	Avg. Scale area (in^2)	Avg. Scale Perimeter (in.)
Pelorosaurus	1852	0.65	0.25	1.79
Kritasaurus	1901	0.49	0.18	1.42
Corythosaurus	1905	0.41	0.10	1.14
Corythosaurus	1912	0.19	0.02	0.51
Chasmosaurus	1913	0.87	0.40	2.44
Triceratops	2002	1.01	0.55	2.82
Unknown Sauropod	2011	0.46	0.46	2.52
Tyrannosaurus	2017	0.04	0.00085	0.11
Slope =		-0.0006653	0.000920	0.001501
n =		8	8	8
Standard Error of Regression		0.347316	0.214515	1.054761
Standard Error (Slope)		0.002121	0.001310	0.006442

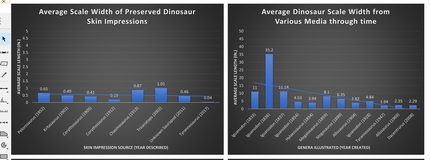
Table 1 - Average Dinosaur Scale Dimensions from Fossilized Skin Impressions

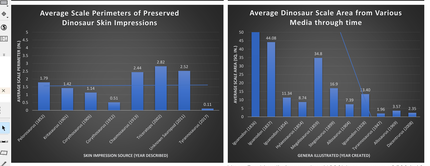
Genus Illustrated	Year Created	Avg. Scale Width (in.)	Avg. Scale area (in^2)	Avg. Scale Perimeter (in.)
Iguanodon	1833	11	-	-
Iguanodon	1836	35.2	520.12	90.32
Iguanodon	1837	11.18	44.08	26.89
Iguanodon	1854	4.53	11.34	12.39
Hylaeosaurus	1854	3.94	8.74	11.02
Megalosaurus	1859	8.1	34.8	22.3
Stegosaurus	1899	6.35	16.9	16.34
Allosaurus	1904	3.82	7.39	10.32
Iguanodon	1928	4.84	13.40	13.90
Tyrannosaurus	1947	1.94	1.96	5.34
Allosaurus	1969	2.35	3.57	6.67
Dacentrurus	2002	2.29	2.35	6.2
Slope =		-0.085335	-0.158508	-1.291078
n =		12	11	11
Standard Error of Regression		8.434665	146.437659	21.468708
Standard Error (Slope)		1.589700	25.090382	3.678412

Table 2 - Average Dinosaur Scale Dimensions from Various Media

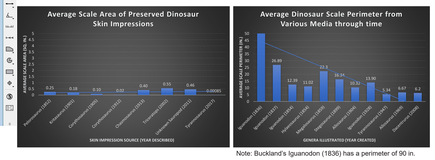
	Scale Width	Scale Area	Scale Perimeter
Difference in Slope =	0.084683	0.159428	1.292579
Standard Error (Difference)	1.589701	25.090382	3.678418
t-stat =	0.053269	0.006354	0.351395
Degrees of Freedom	18	18	18
p =	0.958104	0.995000	0.729371

Table 3 – Results from t-tests comparing scale dimensions in media versus preserved skin impressions over time





Note: Buckland's Iguanodon (1836) has an area of 520 in^2.



Note: Buckland's Iguanodon (1836) has a perimeter of 90 in.

Discussion

Data show that dinosaur scales in the media do get smaller over the course of time but there is no quantifiable connection to the discovery of fossilized skin impressions over the long-term. So why do scales in media shrink over the decades? This may be explained when considering factors such as the time period when the creature was drawn, the "distance" between the observer and subject in a painting or the type of medium used to create the image of the beasts.

When first described, scientists concluded that dinosaurs were up-scaled lizards with proportions similar to modern reptiles, like monitor lizards (Mantell, 1833). This interpretation is reflected in early artistic reconstructions by George Scharff (Fig.1), John Martin (Fig. 2), and Benjamin Waterhouse Hawkins (Fig. 4) who depicted dinosaurs as quadrupedal beasts covered with large scales. The quadrupedal model stayed in vogue until the 1870's when Louis Dollo's work describing the Bernissart Iguanodons concluded that dinosaurs could also be bipedal. But covering dinosaurs with scales persisted, more likely due to dinosaurs being seen as reptilian than discoveries of fossilized skin impressions. Modern paleoartists have access to images of dinosaur skin impressions, allowing them to create realistic reconstructions.

Another consideration regarding the visibility of scales is the distance between observer and subject; large scales would be visible at a greater distance while smaller ones would not. The human eye with ideal, 20/20 vision is able to discern details as small as 0.4 inches (or 5 arc-minutes) across from a distance of 20 feet. This means that most dinosaur scales wouldn't be visible to the typical person beyond just a few tens of feet. Because the earliest interpretations of dinosaurs were that they were overgrown lizards with proportionately sized scales, those scales would be visible from a greater distance. For reference, an eleven-inch scale (the scale size measured in Scharff's 1833 and Martin's 1837 illustrations), at the limit of visual acuity, would be visible from almost 600 feet away.

Of the eight preserved skin samples I examined, the largest average scale size was from a Triceratops, measuring an inch across, and the smallest were associated with a Tyrannosaur (Bell et. al, 2017), measuring 0.04 inches. Based on these averages, the Triceratops scales would be visible from a distance of 53 feet while the scales of a Tyrannosaur would be visible from a distance of just two or three feet. This means that if an artist wants to accurately represent a dinosaur's exterior, they should consider the distance between the dinosaur in the painting and the observer. Should the creature be hundreds of feet away, the scales would not be visible but if at a closer distance, these details could be discernable, depending on the type of dinosaur.

A third consideration is the type of media used to produce a piece of art and whether or not the image can be reworked or updated. Different types of paints have characteristics that appeal to different artists for a number of reasons, including use of dyes or pigments, the surface to which the paint will be applied, or drying times. Dyes, when dissolved in water, produce a transparent layer while pigments, which are actual particles mixed into a medium, producing an opaque appearance. Surfaces primed for a mural will absorb paints differently when compared to canvas or paper. Drying time of the medium influences how long after the paint is applied that it can be reworked. Because watercolor paintings leave the dye behind after drying, they are easily reworked by simply applying a small amount of water to reconstitute the dye, allowing the paint to be reworked at any time. Oil as a medium uses flakes of pigment mixed into an oil that is applied to a surface. The process of drying takes several months so an artist has ample time to rework a piece, if they desire. Fresco paintings, where dyes are applied to wet plaster, are incredibly durable but cannot be reworked after the plaster dries, instead requiring an entirely new layer of plaster to be applied before the paints are added (Mayer, 1981). These differences determine whether or not an artist may have the opportunity to upgrade or modify an image or how much detail they want to include. The plaster to which dyes are applied with a fresco dries out an creates a permanent design, one that cannot be changed. On the other hand, watercolors provide an opportunity to make changes should the artist want to do so since the dyes can be reconstituted.

While my initial data show no correlation between the change in scale size in popular culture media and the discovery of fossilized skin impressions of dinosaurs, this is a broad trend, examined over two centuries. Are there any trends over shorter time periods? Initial scale recreations were quite large but shrank after a few years, around the same time the first dinosaur skin impressions were being described. Early twentieth century artists, like Charles Knight or Rudolph Zallinger, were associated with museums that possessed dinosaur skin impressions. And Charles Knight has a well-documented history of researching live animals to guide his reconstructions of prehistoric creatures so he must have been familiar with the dinosaur skin impressions at the American Museum of Natural History. Many modern day paleoartists are very familiar with recent updates in how dinosaurs may have appeared in life, whether covered with feathers or scales or displaying different colors, and use this knowledge to help recreate more realistic images. Could an in-depth examination of these time periods reveal a trend between scales in artwork and skin impressions? That remains to be seen.

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