11
BONE COLLAGES
MEDIA OF DEEP TIME

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Spread across two pages of an old, worn notebook is a jumble of three-digit numbers connected with dashes and lines into a sort of diagram (Fig. 11.1). What do these clusters of numbers represent? Can anyone read and decipher them? And who created them in the first place? They come from one of the field journals that paleontologist Werner Janensch kept on the Tendaguru dig from 1909 to 1912. The diagram represents a large number of related bones. It describes a location that had such an abundance and diversity of finds that it was almost impossible to separate them and classify them individually. The notes that Janensch made in his journals document not only the bones themselves, but the complex relationships between them, features that escaped notice at first glance when he was still at the dig. The numbers symbolize the remains of fossilized animals, and the lines stand for possible anatomic connections, i.e., for morphological relations. In short, the image is part of a puzzle that was supposed to represent an organism from the distant past, an era best understood in terms of the geologic timescale known as "deep time."

Paleontologists adopted the practices of sketching and drawing used in geology, and used a variety of strategies for the visual representation of their finds and interpretations. Illustrations, diagrams and tables were a fundamental part of their work, both in the field and in the lab. Using these visual media, they attempted to produce coherent descriptions and explanations of deep time. This practice of visualization reached a zenith in the late nineteenth century and early twentieth century.[1] This was the time of the Second Dinosaur Rush, an international race to acquire the world's best dinosaur finds. One spectacular discovery of well-preserved remains followed the next, and dinosaur skeletons, such as the plaster cast replica of the American *Diplodocus carnegii*, were exhibited in natural history museums throughout Europe, attracting enormous public attention.[2] These developments in turn led to more widespread use and further institutionalization of paleontological visualization techniques. What techniques and media were used to reconstruct and exhibit extinct animals? How were the recovered remains ultimately reconstructed in the exhibition hall, and in particular, what role did drawings like those from Werner Janensch's journal play in the transfer of objects from the field to the museum?

Using the example of the Tendaguru Expedition, we will examine successive stages of the fossil reconstruction process and show how different media were used to help assemble the recovered bones and ultimately recreate extinct organisms in their entirety. The Tendaguru Expedition is a particularly rewarding case to examine, because the sketches made by the paleontologists who worked on the dig

Fig. 11.1, *left*
Sketch from Werner Janensch's field journal, 1909–1912. (Tendaguru-Expedition 8.6, Pal. Mus. S II, HBSB, MfN, p. 146.)

* This chapter was translated by Brad Hagen, who also translated all quotations from German sources unless otherwise noted.

1 Rudwick, *Scenes from Deep Time;* Rudwick, *Georges Cuvier*; Rudwick, *Bursting the Limits of Time*; Tamborini, "From the Known to the Unknown."

2 Tamborini, "If the Americans Can Do It"; Nieuwland, *American Dinosaur Abroad*; Brinkman, *Second Jurassic Dinosaur Rush*; Manias, "Building Baluchitherium and Indricotherium"; Rieppel, "Bringing Dinosaurs Back to Life."

allow us to understand how these visualization techniques worked and what they were based on. What practices were Janensch and fellow expedition leader Edwin Hennig able to draw on while in the field? Did they adopt standardized note-taking and pictorial techniques, or did they employ new methods? But before we can begin to look at the reconstruction process and related practices, we must first answer a more fundamental question: What exactly are fossils, scientifically speaking?

FOSSILS

Paleontology is a dual discipline, part history and part biology. It analyzes and illustrates the evolution of life on Earth over time. In doing so, it deals with unimaginably large spans of time—millions or even billions of years—and this has a significant influence on its methodology. The French naturalist Georges-Louis Leclerc, Comte de Buffon (1707–1788), was one of the first to explore the depths of geologic time. Buffon was fascinated by the enormous breadth of this timescale, which positions the events of natural history at temporal distances beyond the bounds of human comprehension. But he also described the ambivalence of time in natural history: while vast temporal dimensions exerted an undeniable fascination, they also cast scientists into a fathomless ignorance from which it is impossible to escape. The paleontological timescale, he wrote, changed our human perspective on nature and made clear the impossibility of truly knowing what happened in the distant past. In 1922, Austrian paleontologist Othenio Abel addressed the problem and summed it up as follows:

> The further back we go into the history of the Earth, … the sparser are the opportunities for comparison with the conditions of the present—we encounter strange and unfamiliar types, long extinct or since transformed to such an extent that they are no longer recognizable; and old acquaintances, forms that are familiar to us from the living animal world, become increasingly rare.[3]

This may lead, Abel continued, to "fantastical speculations that have no deeper scientific value."[4] Fossils, he concluded, are not a reliable point of departure for biological research. And indeed, it is extremely rare to find well-preserved fossils that resemble living organisms and that can be exhibited just as they appeared when they were first discovered. This is because the taphonomic processes[5] that work upon a dead organism destroy and alter its features. Soft tissues almost always decay and even hard parts like bones are seldom fully preserved. In hundreds of cases, the recovered remains of dinosaurs amount to only a few fragments of bone. The vast span of geologic time shapes, alters and destroys the original organism. The fossil record, the totality of all fossils that have been scientifically documented, must therefore remain forever imperfect and incomplete. Fossils are nevertheless the only traces we have of past geologic eras. This is the challenge that paleontologists face. They have no choice but to classify and catalog every fragment they recover and try to fill in the gaps of missing bones in order to draw a meaningful picture of these extinct animals. Visual reproductions consequently play a key role in the generation of paleontological knowledge.

The incompleteness of the fossil record raises several important questions: How do paleontologists go from the fossils, the excavation data and the documentation of their finds to the organism itself, or the complete skeleton as displayed in the museum? How are paleontologists able to recognize fossilized bones in rock layers, distinguish them from the surrounding rock and extract them from it? And what is the process by which incomplete fossils, which provide only a partial representation of an organism, are transformed into scientific data that later becomes the basis for research and the exhibition of extinct life forms?

3 Abel, *Lebensbilder,* V.

4 Abel, V.

5 The term 'taphonomy' (from Greek τάφος 'grave' and νόμος 'law') was introduced in 1940. It refers to the study of the processes of decay and fossilization that occur after an organism's death. Efremov, "Taphonomy."

TO RECOGNIZE IS TO IDENTIFY …

If the reconstruction and mounting of extinct life forms is to be accurate, the collectors who gather their remains must have a practiced eye. Fossils have always been hunted by a broad variety of people: university-educated paleontologists, professional collectors and amateurs. They must all train their eyes to recognize organic forms embedded in rock. As the field of paleontology grew and evolved in the nineteenth century, much effort was given to this training. In 1835, for example, British geologist and paleontologist Henry Thomas De la Beche published a manual with the apt title *How to Observe*. The book was written "to afford assistance to the scientific traveller and student" wishing to make geological observations, and to "be the means of inducing others to collect information."[6] The experienced scientist, explained De la Beche, selects those elements that are important and dismisses anything that might prevent him from concentrating his observations on what matters.

Making a clear distinction between important and unimportant elements is not easy, however, and is sometimes not possible at all. This point was stressed by German geologist Ernst Heinrich von Dechen in his preface to the 1836 German translation of De la Beche's book: "Geognosy would seem even more in need of such instructions than some other branches of the natural sciences, because the difficulties confronting the beginner and the untrained are of a peculiar kind."[7] As von Dechen wrote, disturbing factors cannot always be tuned out by beginners, inexperienced students or even trained geologists.

Paleontologists in the early twentieth century faced these same methodological challenges. The Stuttgart-based paleontologist Eberhard Fraas, for instance, opens his fossil collecting handbook *Der Petrefaktensammler. Leitfaden zum Sammeln und Bestimmen der Versteinerungen Deutschlands*, published in 1910, by arguing the importance of proper paleontological observation. Nature, he wrote, plays tricks on us, and these tricks "sometimes have the power to deceive not only the beginner but even the experienced collector."[8] "Nature's tricks" were how Fraas described rock formations that coincidentally resembled petrified organic forms—that is, fossils. He assured his readers, however, that they "would seldom go astray, if [they] kept in mind that fossils are always to be traced back to hard organic matter, while nature's tricks take completely random forms, which can only be animated through the power of imagination." According to Fraas, in other words, the paleontologist will be able to properly identify fossils if he is able to recognize them as petrified life forms. The recognition and identification of fossils as the remains of deceased organisms constitutes the essence of fossil collecting, and thus "the value of the collection" lies in the identification of these remains: "The fossilizations themselves are dead, meaningless material and it is only the identification and interpretation of the remains that restores them to life in our mind's eye."[9]

It is this "interpretation of the remains" that defined paleontological expertise in the early nineteenth century and established paleontology as an independent biological discipline. This approach to paleontological field work—and later lab work—was established in *Recherches sur les ossemens fossiles de quadrupèdes* (Research on quadruped fossil bones), written in 1812 by Georges Cuvier, who laid down the theoretical foundations of paleontology and established it as a scientific discipline. The approach was based on examining fossils from the standpoint of comparative morphology, a method he had previously developed in the field of anatomy.[10] The principle underlying this method was Cuvier's law of correlation. It states that certain anatomical features always occur in conjunction or correlation with others, so that one can infer aspects of the organism as a whole from the presence of individual features. Fraas summarized this law as follows: "Starting from a bone or tooth, we can, according to the laws of comparative anatomy, draw

6 De La Beche, *How to Observe*, v.

7 De La Beche, *Anleitung zum naturwissenschaftlichen Beobachten*, iv.

8 Fraas, *Der Petrefaktensammler*, 39.

9 Fraas, 39.

10 Rudwick, *Georges Cuvier.*

definite conclusions regarding the animal as a whole and sometimes even regarding its mode of life and the conditions of its existence."[11] Comparative anatomy was the foundation upon which the visualization practices of paleontology were built,[12] and the practice that grew out of it—comparative morphology—became a second essential condition of paleontological work: Fossils must be depicted, because visual reproductions facilitate and complete the process of paleontological identification.

... AND TO IDENTIFY IS TO DRAW

"The identification of fossils is mostly based on comparison with a picture."[13] These words from the authors of *Paläontologisches Praktikum*, a seminal textbook on paleontology published in 1928, sum up the essence of paleontological identification in the field. To understand the role played in this process by pictures, we must analyze how they are used in the course of a paleontological expedition. Valuable insight into this question can be gained by studying the Tendaguru Expedition.

After the enormous bones were discovered in German East Africa, paleontologist Eberhard Fraas, who happened to be in the area at the time, was asked by the colonial government to travel to the site of the finds, which was located near the town of Lindi. His mission was to conduct a close examination of the finds, and to find out "in particular, whether they are fossils or recent remains …, and to [assess their state of] preservation, and their ability to withstand transport and excavation … ."[14] The first step in this process was to identify the finds; this would allow him to determine whether it was worth collecting them and possibly transporting them to Germany. Fraas consequently made drawings of everything he found in the field and also took some photographs. This made it possible to get an overall picture of the incomplete and partially damaged finds, and subsequently to identify the fossils with greater precision. Several months later, he published these drawings along with written descriptions of the finds in the prestigious journal *Palaeontographica*.

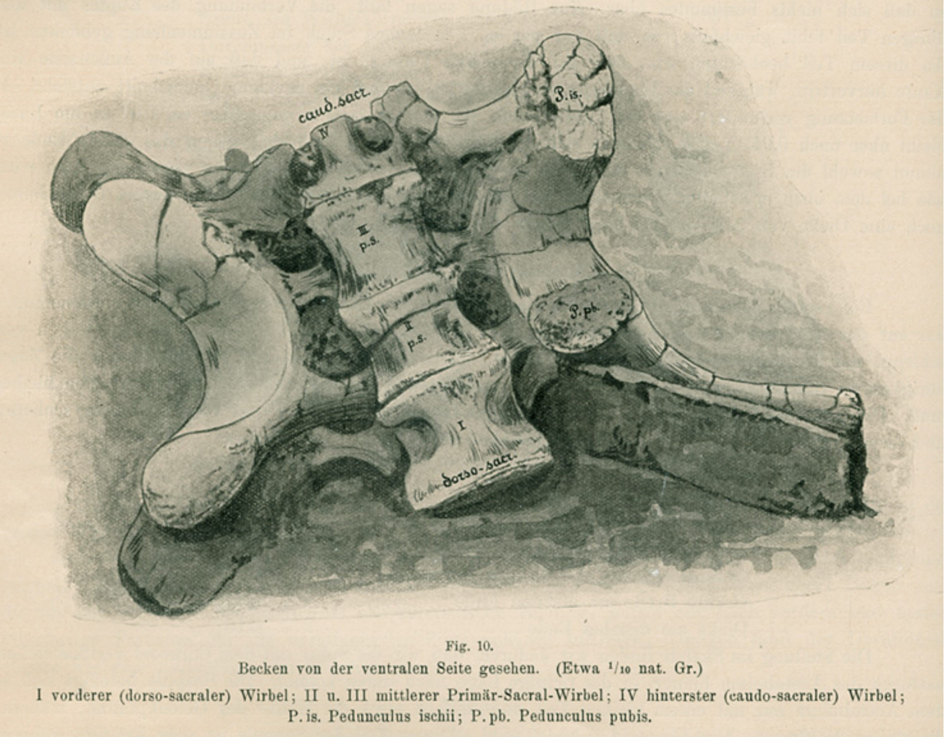


Fig. 11.2
Drawing of the pelvic bone of a dinosaur. (Fraas, "Ostafrikanische Dinosaurier," *Palaeontographica,* 126.)

The individual stages of the identification process can be illustrated using one of the drawings made by Fraas. While in the field, he found well-preserved bones belonging to two separate species of a genus that he initially named *Gigantosaurus* in the (mistaken) belief that the name was not taken. In the first decade or so after the expedition was completed, the two species were reclassified multiple times. In 1911, they were renamed *Tornieria africana* and *Tornieria robusta*;[15] in 1922, the former was renamed *Barosaurus africanus*.[16] Since most of the pelvic bones of the type specimens were destroyed (the single exception being the ischium, that is, the lower and back part of the hip bone), it was crucial that the scientific community be made aware of the better preserved, if similarly fragmentary, pelvic bones

11 Fraas, *Der Petrefaktensammler*, 3.

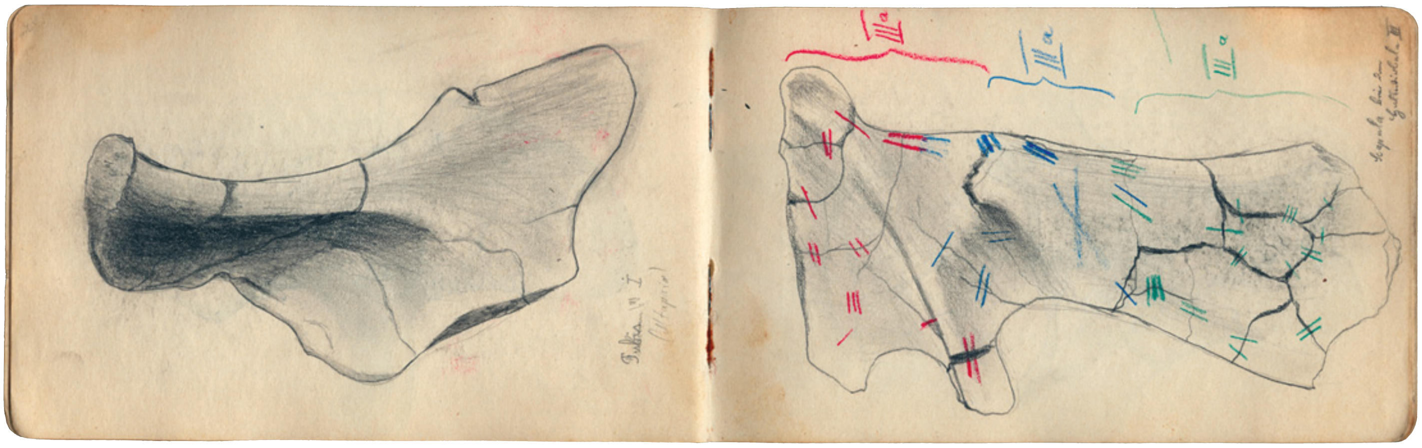
12 Sepkoski, *Rereading the Fossil Record*; Sepkoski and Ruse, *Paleobiological Revolution*; Sepkoski and Tamborini, "An Image of Science"; Tamborini, "Die Wurzeln der ideographischen Paläontologie."

13 Seitz and Gothan, *Paläontologisches Praktikum*, 95.

14 Fraas, "Ostafrikanische Dinosaurier," *Palaeontographica,* 106.

15 Wild, "*Janenschia n.g. robusta*," 2.

16 Janensch, "Das Handskelett."



of a different specimen assumed to belong to the same genus. As it happened, however, "transport of the fragmented and severely damaged piece [was] unfortunately impossible." As a workaround, Fraas proposed to "document the piece using photographs and drawings" and then create a three-dimensional model "on the basis of these original photographs … , sketches and dimensions."[17] Based on his drawing and numerous photographs of the incomplete piece, Fraas produced a coherent illustration and published it in *Palaeontographica* (Fig. 11.2).

The same methods were used by the paleontologists sent to conduct large-scale excavations at Tendaguru by Berlin's Museum für Naturkunde in 1909. Edwin Hennig and Werner Janensch produced minutely detailed drawings of what they saw in the field and, whenever they could, they sketched in the missing parts of the incomplete bone fragments.

Figure 3 shows a scapula (shoulder blade) that was too fragile to transport as a single piece. The paleontologists therefore decided to divide it into three parts while still in the field, and they marked the outlines of these parts in the drawing, using a different color for each part. As in this case, it was crucial throughout the Tendaguru Expedition to depict the paleontological finds as precisely and accurately as possible, in order to facilitate subsequent paleontological work. It was these depictions, which recorded not only the finds themselves but how they related to other finds in the field and what the paleontologists did with them, that, later in Berlin, allowed preparators to properly perform their work and scientists to produce descriptions of the finds. The sketches from the field journals were thus used as a tool in the field while also serving as drafts for illustrations of the bones published in scientific periodicals. The publication of these pictures and accompanying descriptions made the finds, and the ecological and geological conditions that resulted in their fossilization, accessible to the wider scientific community. As the procedure used by Fraas shows, the fragmentary, imperfectly preserved fossils acquire a certain completeness through the combination of a variety of media, including photographs, sketches and diagrams.

Paleontological illustrations and photographs served other purposes, too, however. In addition to depicting finds, they also aided identification by providing material for morphological comparisons. Fraas compared the fossils that he had sketched with illustrations from textbooks and scientific papers showing species that had already been classified. Comparing these illustrations allowed him to define the differences and commonalities between known specimens and unidentified finds. In the best case, this allowed the new finds to be assigned a definite place within the system of biological taxonomy. On the basis of these comparisons, Fraas became convinced that the Tendaguru finds belonged to a new and as yet unclassified species, which he named *Gigantosaurus africanus*. The next step was to connect the newly named dinosaur group with previously identified groups in order to clarify possible evolutionary relationships. Pictures played a decisive role in this process, as can be seen in Fraas's publication of 1908:

Fig. 11.3
Sketch of a shoulder blade from a field journal (right side). (Tendaguru-Expedition 8.1, Pal. Mus. S II, HBSB, MfN.)

17 Fraas, "Ostafrikanische Dinosaurier," *Palaeontographica*, 126.

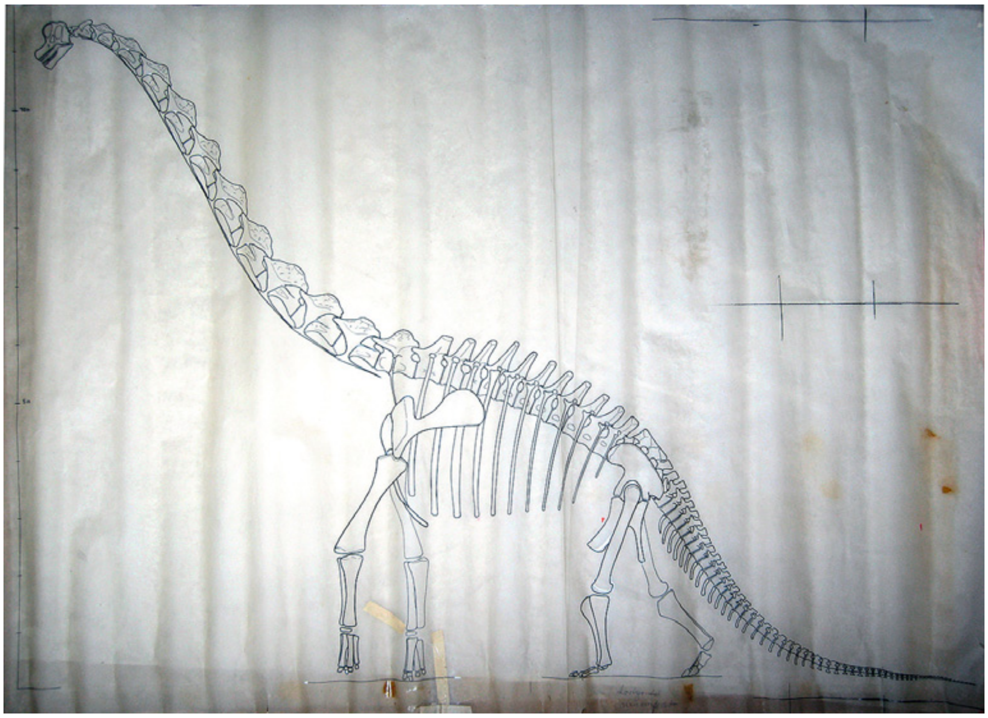


Fig. 11.4.
Sketch for the reconstruction of the *Brachiosaurus brancai* skeleton. (Pal. Mus. B X 35, HBSB, MfN.)

> Based on a comparison of the dinosaur group introduced as *Gigantosaurus* with other known species, it would appear entirely certain that we must place this new group among the dinosaurs and more specifically in the subgroup of *Sauropoda MARSH*. Apart from the strongly procoelous anterior caudal vertebrae, all of the features of *Gigantosaurus* are consistent with those of the Saurapoda [sic].[18]

This second important function of pictures as an aid in recognizing and classifying fossils was important not only for the scientists involved in the Tendaguru dig but also for the Africans who assisted them. This point was made by Werner Janensch in a letter to Wilhelm von Branca, director of the Geological and Paleontological Institute and Museum in Berlin: "Our people, especially the overseers and excavators, are very interested in the pictures in Zittel, which we must often show them."[19] In other words, Zittel's *Handbuch der Paläontologie*[20] was used on-site as a primary reference for identifying the excavated fragments of bone—although it did not necessarily lead to taxonomic clarity in every case, as indicated by a subsequent letter written to Branca: "In the case of Skeleton S, by the way, small elongated appendicular bones were recovered, as well as very elongated cervical vertebrae. I am not able to say, based on Zittel, whether these are the remains of birds or pterosaurs."[21]

Finally, pictures played an important supporting role in the reconstruction of organisms that were only partially preserved (Fig. 11.4).[22] By making it easier to visualize the organism as a whole and as a complete being, they paved the way for the reconstruction of the specimen and the steps leading up to the mounting of the skeleton for exhibition purposes.

To sum up, paleontological illustrations and photographs have at least three interrelated functions: First, they depict fossil finds. This provides other paleontologists with the raw material of a dig, and they will use that material for work of their own. Second, the reproductions published in textbooks and reference works make it possible to compare and identify fossils that have only survived as fragments in rock. Third, fossils that have been found only partially preserved are reconstructed as complete life forms with the aid of pictures—for the purpose of exhibiting them, for instance. Illustrations and photographs therefore constitute one of the foundations of paleontological work; they are necessary but not in themselves sufficient.

TABLES AND METADATA

The numerous drawings and diagrams that Fraas, Janensch, Hennig and the African excavators created in the field were necessary to identify the finds. But other forms of knowledge and other media were required to turn the fossils into something suitable for exhibition in a museum, or something that would be presented as a type specimen in textbooks or scientific papers. In these cases, bureaucratic knowledge played a central role.

18 Fraas, "Ostafrikanische Dinosaurier," *Palaeontographica,* 126.

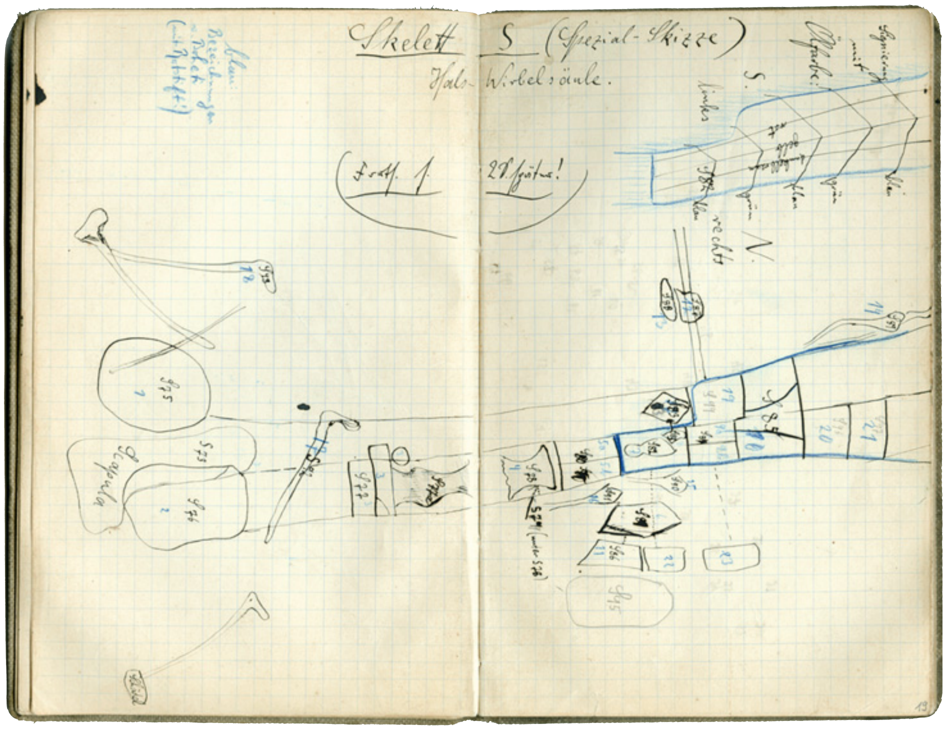
19 Werner Janensch to Wilhelm von Branca, October 7, 1909, Tendaguru-Expedition 5.1, p. 38, Pal. Mus. SII, HBSB, MfN.

20 Tamborini, "Reception of Darwin"; Tamborini, "Paleontology and Darwin's Theory of Evolution."

21 Werner Janensch to Wilhelm von Branca, September 10, 1910, Tendaguru-Expedition 5.1, pp. 121–22, Pal. Mus. SII, HBSB, MfN.

22 A comparison of this approach with archaeological practices would exceed the scope of this study. See Klamm, *Bilder des Vergangenen.*

Over the course of the nineteenth century, the transfer of knowledge between the fields of bureaucracy and natural history that began in the 1700s became increasingly institutionalized[23] and reached a peak during the paleontological expeditions of the mid-nineteenth and early twentieth centuries. For example, paleontologists were using tables and quantitative practices that had long been established in the cameral sciences. These bureaucratic techniques formed a key part of their work with paleontological illustrations. Like good archivists or civil servants, paleontologists recorded exactly what was present in the different strata so they could archive this information in tables and lists.



This applied, too, to the paleontologists at Tendaguru, who seemed to resemble bureaucrats more than scientists as they diligently monitored, watched over, noted down and labeled what was excavated. For each of the finds, they recorded metadata such as stratum and location, so that once the bones were back at the museum, they could be correctly identified and combined. An important part of this work was to create illustrations documenting exactly how the bones had been found in the field.

The sketches in Werner Janensch's notebook (Figures 11.5 and 11.6) serve as a vivid indication that the drawings were completed in several steps. He used a blue pencil, for example, to add the notes of the overseer and chief preparator Boheti bin Amrani.[24] Every bone was then numbered so it could be identified later in the museum. This shows that the creation of the drawings was a cooperative effort in which a variety of specialist knowledge was shared.

Fig. 11.5, ***top***
"Special sketch of Skeleton S" in Werner Janensch's notebook. (Tendaguru-Expedition 8.2, Pal. Mus. S II, HBSB, MfN.)

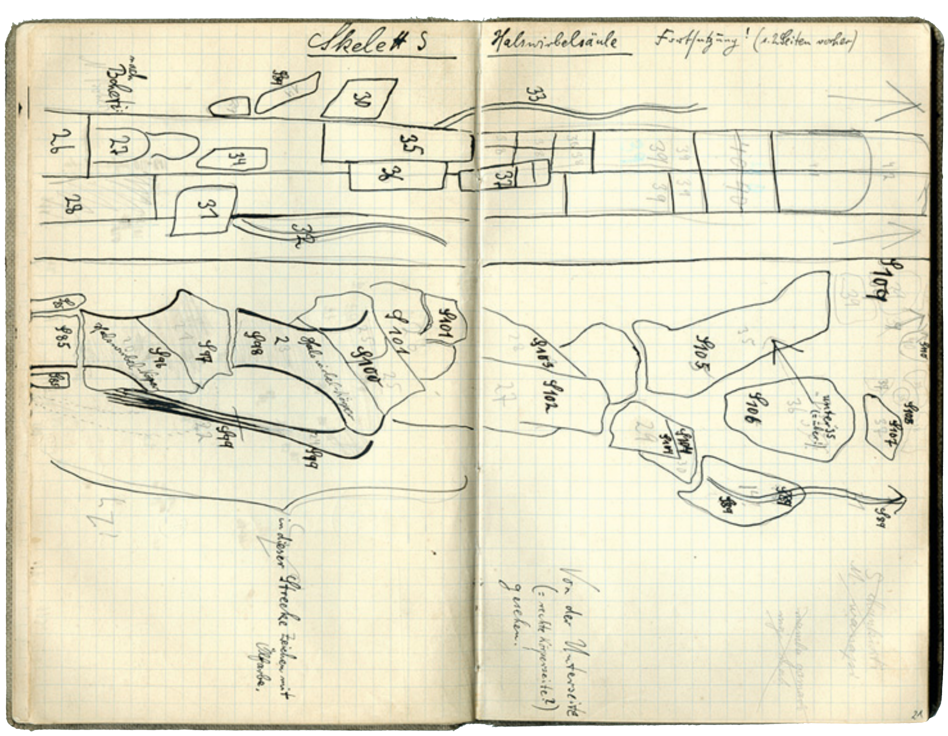
Fig. 11.6, ***bottom***
"Cervical spine of Skeleton S" in Werner Janensch's notebook. (Tendaguru-Expedition 8.2, Pal. Mus. S II, HBSB, MfN.)

23 Sepkoski and Tamborini, "An Image of Science"; te Heesen, "Accounting for the Natural World"; Koerner, *Linnaeus*.

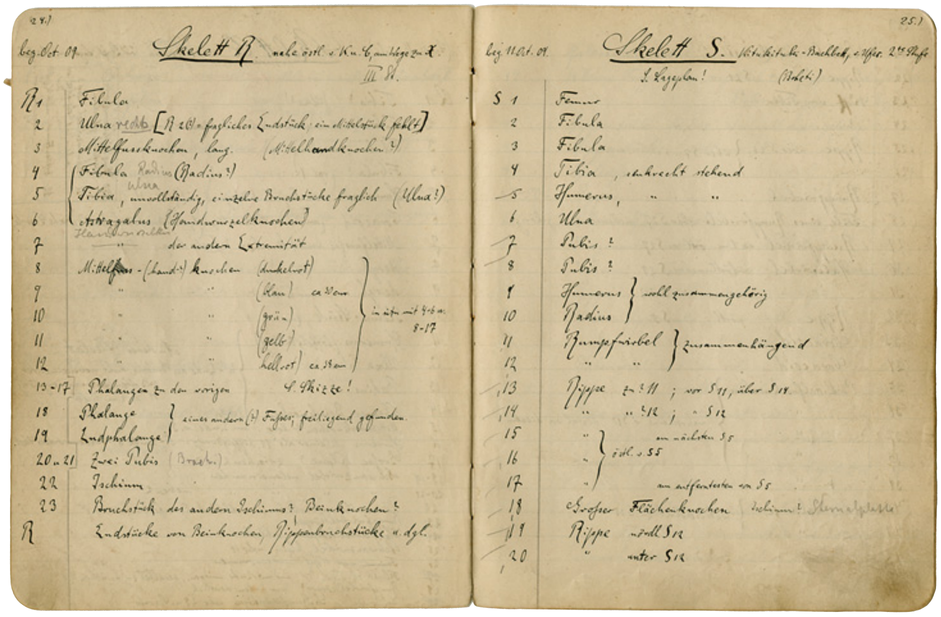
24 Regarding Boheti, see "Taxonomies at Tendaguru," pp. 232–253.

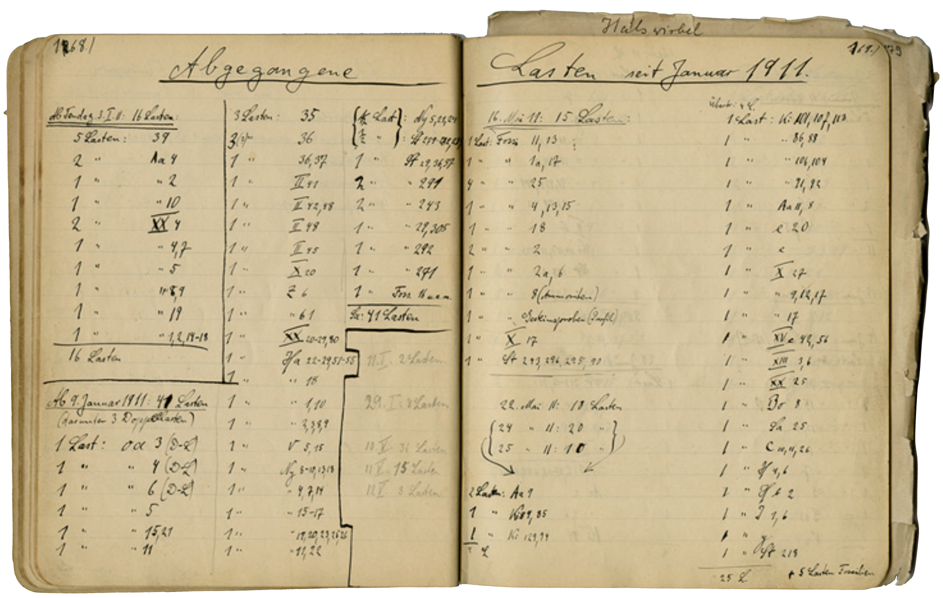
25 Rudwick, *Scenes from Deep Time*. A comparison with zoological practices lies outside the scope of this study. See Ohl, *Art of Naming*.

Next, two drawings were made of the numbered bones: in one, they were integrated into a skeletal reconstruction; in another, they were depicted in the context of the find-spot. These drawings were based on lists of the numbered bones (Fig. 11.7). Finally, the shipping crates were numbered, and the shipments were carefully and systematically documented (Fig. 11.8).



As a result of this bureaucratization of paleontological work, the metadata represented in tables, labels and other bookkeeping media became extremely important.[25] This is because the object and its metadata only acquired scientific significance as an integrated unit: "Fossils without a precise indication of where they were found have practically no value





at all," the paleontologist Ernst Stromer once noted succinctly.[26] The value of fossils is therefore determined by the quality of their metadata. In fact, as far as the species description and many other paleontological questions were concerned, the metadata was actually more important than the fossils. Paleontologists in the German-speaking world were not the only ones to comment on this epistemic reversal—that is, the fact that the actual insight is gained from the metadata and not the object itself. In a speech he delivered in 1908, Adam Hermann, the chief preparator of the Department of Vertebrate Paleontology at the American Museum of Natural History, likewise stressed the central role of metadata:

> The most important thing in packing is to save the field labels. … I have found in my experience that some collectors do not pay attention enough to the packing and the labeling of the different parcels. This is one of the most important parts of collecting and should never be neglected. … It is the duty of the preparator to save these labels, that is to remove them from the specimen if pasted on, before preparing, or cut them out of the wrapper, and keep them for reference.[27]

Labels were supposed to be retained and preserved, because they provided the syntax or the instructions, as it were, for the reconstruction of the specimens. The last phase of this media-assisted work thus began when the carefully labeled finds arrived at the museum. The paleontologists involved in the Tendaguru Expedition then used the metadata recorded on labels, in books and on lists to interpret the drawings of the bones. This allowed them to begin assembling a physical skeleton, the last step before the extinct animal is exhibited in the museum.

LIFELIKE REPRODUCTIONS OF THE PAST

In his essay *Wert plastischer Rekonstruktionen fossiler Wirbeltiere* (The value of physical reconstructions of fossil vertebrates), the paleontologist Othenio Abel drew attention to the importance of reconstructing and exhibiting fossil vertebrates: "Since the North Americans started producing scientifically sound three-dimensional reconstructions of fossil animals, European paleontologists have begun taking [it] more seriously again."[28] Abel concluded his essay by asserting that "the physical reconstruction of fossil vertebrates is the most felicitous adjunct to scientific research that one can imagine."[29] But how is it even possible to reconstruct fossil vertebrates, whether as models or as skeletons (such as those we see in natural history exhibitions)?

Fig. 11.7, *top*
11.7. List of bones belonging to "Skeleton R" and "Skeleton S." (Tendaguru-Expedition 8.6, Pal. Mus. S II, HBSB, MfN.)

Fig. 11.8, *bottom*
Packing lists for the excavated bones. (Tendaguru-Expedition 8.6, Pal. Mus. S II, HBSB, MfN.)

26 Stromer, *Paläozoologisches Praktikum*, 8–9.

27 Hermann, "Modern Laboratory Methods," 286.

28 Abel, "Über den wissenschaftlichen Wert," 3.

29 Abel, 3.

The paleontologist Edgar Dacqué described how to do this in 1928: "The basis for the entire reconstruction is first of all the procurement of all the body parts, all the skeletal bones."[30] But before these bones could be procured, he wrote, the fossils first had to be analyzed. As a look at the lists, tables and illustrations created in the field will show, "every vertebrate skeleton, with the exception of fishes, is different, [since] these skeletons cannot normally be retrieved in their entirety from the strata in which they are found." The remains "must therefore be supplemented [with other parts]."[31] Once illustrations were made of the missing and incomplete bones from the field, it was possible to create a physical reconstruction of the animal. This was done by combining all of the parts that belonged either to the excavated specimen or to one or more different specimens of the same species. Reconstruction is like a collage, and as a result of this technique, Dacqué noted, "most of the fossil skeletons in our museums are composed of the remains of multiple individuals, or they have had parts added to them."[32]

This applied to the *Brachiosaurus brancai* skeleton as well. In fact, this specimen serves as an excellent example of how the "procurement of … all the skeletal bones" was accomplished.[33] Janensch described this elaborate process in detail: "For the modelling of the skull, the existing facial bones of Skeleton S II were used, … and Skull tl (a complete skull) served as a template for what was still missing … ."[34] He continued: "Elements that were missing from some of the limbs and their girdles on one side were copied based on existing bones from the other side, or else replaced by other finds of the right size, or almost the right size. … The latter applies as well to those parts of the axial skeleton that are completely absent. … Missing parts that were not available in the right size had to be modeled as enlarged versions of smaller pieces."[35] The list compiled by Janensch of all the

Fig. 11.9
Preliminary assembly of *Brachiosaurus brancai* in the museum attic, circa 1937. (Pal. Mus. B III 92. HBSB, MfN.)

30 Dacqué, *Das fossile Lebewesen*, 57.

31 Dacqué, 57.

32 Dacqué, 57.

33 The mounted dinosaur skeletons did, in fact, normally consist of a) original bones, b) plaster cast bones and c) modeled plaster bones.

34 Janensch, "Die Skelettrekonstruktion," 98.

35 Janensch, 98.

parts that had to be added to the skeleton is several paragraphs long. The addition of other finds or reproductions was necessary, however, in order to achieve the reconstruction of a complete specimen.[36]

When paleontologists are faced with the task of physically reconstructing and mounting an unknown organism, they have no choice but to rely on comparative morphology when assembling their fossil collages and deciding where the various pieces of the puzzle might fit. In order to decipher the "biological character" of the fossil animal, on the other hand, they turn to illustrations in textbooks or scientific journals:

> The structure of the extremities, the arrangement of the joints and hundreds of [other] details are dictated by the complementary differences [of their constituent parts] and can only be understood with reference to the 'biology' of the animals. Only when the biological character of the fossil animal is taken into consideration is it possible to produce an [anatomically] sound reconstruction out of individual skeletal parts and properly mount the skeleton.[37]

It was on this basis that Janensch reconstructed the parts of the *Brachiosaurus* that were either incomplete (the spine, for example) or, in some cases, missing entirely. Almost twenty years after the expedition, he was still able to reconstruct the relationships among individual bones that had been recovered from their natural archive in the soil and thus properly combine, separate or augment the respective parts of the skeleton. What allowed him to do this was an analysis of the metadata that he had recorded in illustrations and tables during the dig. Janensch was able to determine, for instance, that the "excavations at find-spot S in the middle dinosaur marl yielded presacral vertebrae from two different specimens of *Brachiosaurus brancai* of different sizes."[38] At the same time, however, gaps in the recovered remains were also apparent: "Whereas [the anterior series] is well preserved, the upper part of the posterior series has been eroded by an external force, presumably moving water, at one level from the ninth to the fifteenth vertebra, so that, except for the vertebral bodies, little else has been preserved other than, in some cases, the prezygapophyses."[39] Janensch was able to overcome this difficulty through recourse to comparative morphology: "With the morphological findings, it was possible to draw inferences based on comparisons and interpolations, which provided a relatively reliable overview of … the gaps."[40] After the missing portion of the reconstruction was filled in through morphological comparisons, a model was made of the vertebral column and the *Brachiosaurus* was mounted with the aid of a wooden scaffold (Figures 11.9, 11.10 and 11.11).

Janensch continued: "The results of this work on the vertebral column of *Brachiosaurus* were put to use in the physical reconstruction of the skeleton that was mounted in the atrium of the Museum für Naturkunde; they were visible in the presacral and sacral vertebrae that were so carefully and attentively modeled by chief preparator E. Siegert."[41] As the reconstruction of *Brachiosaurus brancai* at the Museum für Naturkunde shows, the physical reconstruction of fossil vertebrates is only possible through the use of various media in combination with biological expertise.

A history of paleontology that aims to examine the historical conditions under which this discipline took shape as a science would be incomplete without an analysis of the complex relationships between paleontological knowledge and the media it employs. A variety of media are used during the successive stages of paleontological work. While biological knowledge allows paleontologists to identify and excavate fossils in the rock, these objects would have no value without the metadata describing where they were found and what else was recovered at

Fig. 11.10
Scaffold used to mount *Brachiosaurus brancai* in the atrium of the museum, 1937. (Pal. Mus. B III 117, HBSB, MfN.)

36 Interestingly, the sequence of steps that is followed to mount the skeleton is the same as that used for paper technologies: reconstruct, supplement missing parts and model them.

37 Dacqué, *Das fossile Lebewesen*, 59.

38 Janensch, "Die Wirbelsäule," 33.

39 Janensch, 33.

40 Janensch, 31.

41 Janensch, 31.

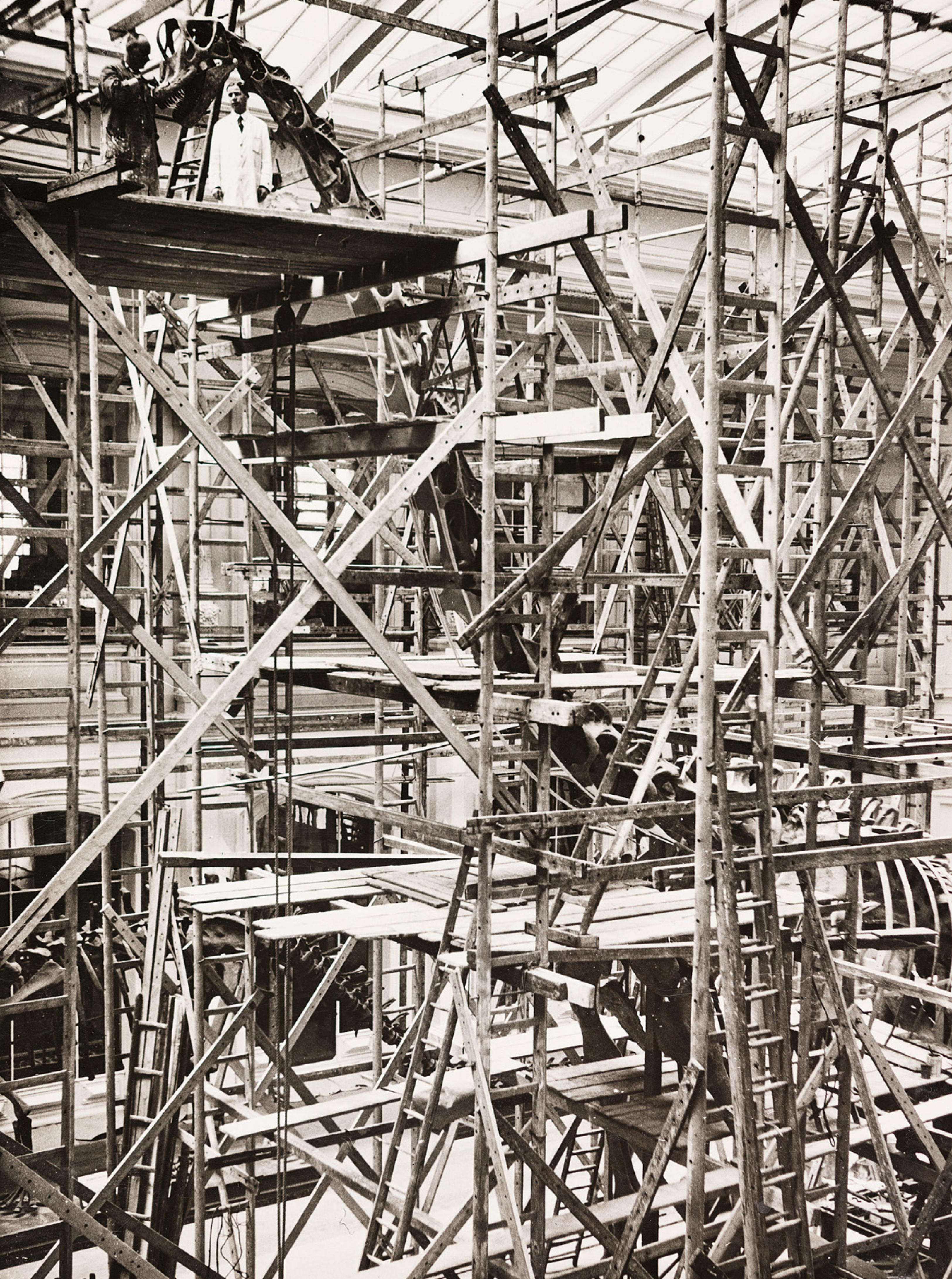


Fig. 11.11
Vertebral column of *Brachiosaurus brancai* against a white backing with crop markings for publication in a scientific journal, 1937. (Pal. Mus. B III 132, HBSB, MfN.)

the same spot, or nearby. To retain this metadata, scientists rely on illustrations, tables and lists. The metadata preserved in illustrations, tables, lists, diagrams and registers facilitates the process of deriving paleontological and morphological knowledge. It helps preparators assemble related sets of bones in the museum and reconstruct the skeletons of completely extinct organisms. Media are therefore indispensable for the work of paleontology. Conversely, advances in morphological knowledge inevitably lead to increasingly accurate illustrations of extinct animals. These illustrations, in turn, are used as reference materials to fill in the parts of the organism that have not been preserved. In this process, the materiality of the excavated, fossilized creatures is translated into abstract forms and figures like the numbers, lines and cross references seen in the diagram mentioned at the beginning of this chapter (Fig. 11.1). Although it will appear cryptic and largely unreadable to many, this diagram has a specific scientific function; it represents a certain step in the paleontological workflow and depicts a certain degree of abstraction in the translocation of the objects and associated data from the field to the museum, and in the process of scientific identification and reconstruction. At the same time, the diagram possesses a symbolic function, in that it refers to the complex materiality of the field work, and to the way in which what was found in the field was translated into a variety of types of media through various stages of abstraction. And that, in turn, shows the inseparable connection between media, scientific expertise and theories: without prior paleontological knowledge, the jumble of numbers in this diagram cannot be read and deciphered; on the other hand, without this representation of the finds, the wealth of the excavation site with its many and diverse specimens would remain invisible and untapped. In sum, a creature such as *Brachiosaurus brancai* is identified and mounted through the interplay of biological knowledge with a variety of media. This is not so much a matter of prioritizing one medium over another, or the hierarchization of media on the one hand and biological theory on the other. Rather, both sides are dependent on one another, and are almost impossible to separate in practice. ■

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