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The 'Spin' in *Spinosaurus*: inventing a modern dinosaur superstar

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Teeth bared, wreathed in dry ice, the creature dominates the cover of the October 2014 *National Geographic*. It fits onto the page only because of its dramatic backwards head-flick, and even then, the end of its slender tail – *too* slender, it is now suspected – has had to be cropped out. It fills the cover both with size and action. It has no background, and needs none, although a wider shot of the same model inside the issue (Mueller, 2014: 101–2) shows that it is surrounded here by theatrical equipment, literally stepping into the spotlight. Both on the cover and in the article, the challenge to the dinosaur orthodoxy could hardly be more straightforward: 'Move over, *T. rex*: The biggest, baddest carnivore to ever walk the Earth is *SPINOSAURUS*' (Mueller, 2014: 101).

Tyrannosaurus rex is the obvious comparison to make when introducing a charismatic new dinosaur to the public, both because of its household familiarity and its literally regal name. The contents page of this *National Geographic* calls *Spinosaurus* 'King Cretaceous', surely another direct jab at the world's most iconic theropod (the predatory dinosaur lineage) and perhaps a necessary nickname given the practical and descriptive *Spinosaurus aegyptiacus* – 'Egyptian spined lizard' (Figure 4.1). But by even admitting that *Spinosaurus* needed introducing, *National Geographic* undoes some of its own argument. As the article goes on to explain, *Spinosaurus* was not 'new' at all. It was first described, in fact, just a decade after *T. rex*, and had been largely ignored by popular culture for the better part of a century.

Figure 4.1 *Spinosaurus* model at the Museu Blau, Barcelona (shared to Wikimedia Commons by user Enric). This is the model pictured on the front cover of the October 2014 *National Geographic*, against a black background and surrounded by dry ice, beside the words 'MOVE OVER, T. REX.' The subheading 'The Quest for the Biggest, Baddest Predator on Earth' appeared beneath its tail. Also advertised on this cover were stories on 'The Truth about GMOs,' 'Drought in the West,' and 'Nuclear Tourism.' CC-BY-SA-4.0 [https://commons.wikimedia.org/wiki/File:035_Spinosaurus_davant_el_Museu_Blau,_pl._Leonardo_da_Vinci,_F%C3%B2rum_(Barcelona).jpg].

Nor was this the first attempt to bring *Spinosaurus* into the public eye. In 2001, film director Joe Johnston had made it the antagonist of *Jurassic Park III*. Here again, direct comparison with *Tyrannosaurus* was the mode of argument: not only does the upstart's distinctive skeleton replace *T. rex*'s on the iconic *Jurassic Park* logo, but it fights and easily beats a *T. rex* on our first encounter with it. Despite this, it is clear in the movie that knowledge of *Spinosaurus* is restricted only to the ultra-experts: Billy Brennan (Alessandro Nivola), an associate professor in palaeontology, asks his boss Alan Grant (Sam Neill) if he thinks it might be a *Suchomimus* – which has a similar-looking head – despite the fact that *Suchomimus* had been first described only three years before *Jurassic Park III* came out. 'Not with that sail,' Grant replies, referring to the unique and very

obvious character which had entered palaeontological literature eighty-six years earlier, instantly recognisable to any dinosaur expert or child with a decent dinosaur book.

Why hasn't Billy heard of this long-established, charismatic predator, even though he's familiar with *Suchomimus*, and thus obviously up on the most recent technical publications of the time (Sereno et al., 1998)? Why, following the enormous publicity implied by *Jurassic Park III*, does *Spinosaurus* need propping up against *Tyrannosaurus* for its reintroduction by *National Geographic* in 2014? A colleague of Stephen Jay Gould famously proposed a three-word formula to explain the archetypal popularity of dinosaurs – 'big, fierce, and extinct' (Gould, 1995: 223) – but *Spinosaurus* met all of these criteria for decades without attracting any serious publicity. It met them better, in at least some respects, than the most well-known dinosaurs in the children's playroom. How, then, can its absence – and presence – in popular culture be understood?

The answer to this may lie in the peculiar and perhaps unique circumstances regarding the 'canonisation' of *Spinosaurus* into popularised palaeontology, the history of which we review here. Given that the science on *Spinosaurus* remains controversial at time of writing (late 2023), our perspective can only be a snapshot of dinosaur science and culture in flux: readers of this chapter just a few years from now may know a different *Spinosaurus* to the one we are familiar with today. But even as the science of *Spinosaurus* moves on at pace, its history shows that the adoption of prehistoric animals into mainline culture or even the subculture of popular science requires a combination of science and art, and *Spinosaurus* is arguably a superior case study than better-known animals because of its complex history of popularisation. It is a story of slow, relatively low-key acquisition into enthusiast-driven conversations followed by major, self-conscious attempts to launch it into the wider dinosaur pantheon by prominent media corporations.

Although those efforts can be said to have been successful, and *Spinosaurus* is now part of the standard 'dinosaur canon', its attainment of this status has not been straightforward or uncontroversial. This may reflect another important factor at play: the enigmatic quality of the beast itself and the inherent difficulties in restoring it. Unlike many other well-publicised dinosaurs, *Spinosaurus* has continually morphed and transformed in scientific interpretation and artistic restorations over the last century, such that dramatic 'reinventions' have provided unique angles, challenges and opportunities for exploitation (Figure 4.2).

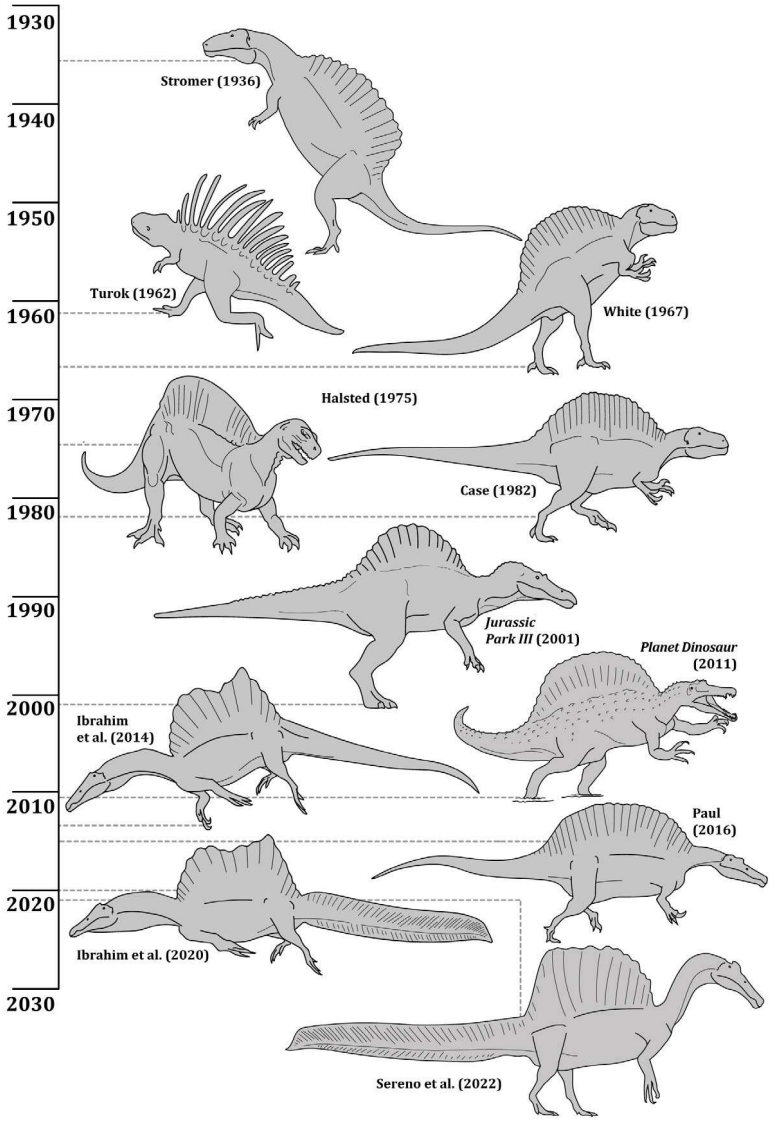

Figure 4.2 The ongoing evolution of *Spinosaurus* in published works and major media products. Although it is not unusual for concepts of a dinosaur's appearance to change over time, our ideas of *Spinosaurus* appearance have evolved in an increasingly public space, and the rate of modification and reinterpretation has gathered pace in the last two decades. © Mark Witton.

'An exercise in pure fantasy'

The issue of 'restorability' – in essence, whether artists and scientists are able to produce a defensible vision of an extinct organism from available fossil material – has run through the history of *Spinosaurus* research and remains evident today. Though first described by Ernst Stromer in 1915, *Spinosaurus* was known for most of the twentieth century only from its type fossil, destroyed during a British air raid on Munich in April 1944. Detailed drawings of these remains survive in Stromer's descriptive papers, showing that the specimen was very incomplete, consisting principally of a jawbone, some teeth, vertebrae (including parts of the iconic sail), and ribs (Stromer, 1915) (Figure 4.3), while a secondary specimen – of dubious relation to the first – revealed details of the hindlimbs (Stromer, 1934). Tantalising as these remains were, their capacity to reveal whole-body insights into *Spinosaurus* anatomy was questioned by Stromer as early as 1936 (see below). Decades later, influential palaeoartists such as Mark Hallett maintained similar views – there was simply not enough material available to understand what *Spinosaurus* looked like:

> The artist and consultant must sometimes decide whether a restoration should be attempted at all. *Spinosaurus*, confidently depicted in popular illustrations as a megalosauridlike [sic] theropod with a 'sail', is very poorly known and may not even be a dinosaur. When it was proposed as an illustration for a recent book, my consultant, Robert A. Long of the University of California, Berkeley, and I decided that a painting of this animal would be an exercise in pure fantasy and should not be attempted until more complete remains are described.
>
> (Hallett, 1987: 99)

Even as new *Spinosaurus* remains began appearing in the late 1990s, they remained difficult to interpret and integrate with other fossils. This is still the case today after the discovery of Faculté des Sciences Aïn Chock specimen FSAC-KK 11888 (Ibrahim et al., 2014a), the most significant *Spinosaurus* fossil since the early twentieth century. Even with this new data, the life appearance of *Spinosaurus* remains controversial and open to dramatic changes. Some of these reflect new discoveries, such as when the team behind the FSAC-KK 11888 finds published their 2020 re-envisioning of the animal, catching significant public attention with a newly found, purportedly water-adapted tail (Ibrahim et al., 2020a).

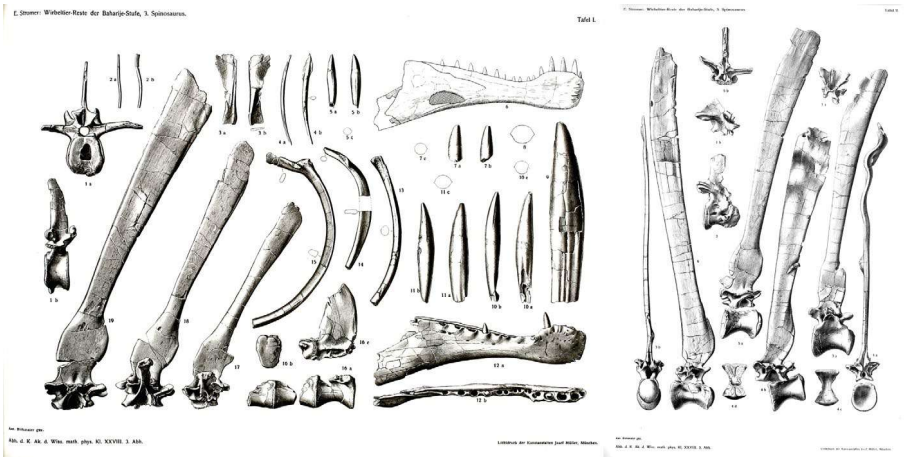

Figure 4.3 The original *Spinosaurus aegyptiacus* fossils described and figured by Stromer (1915), later destroyed during World War II. Image in public domain, obtained from Biodiversity Heritage Library.

Associated with these updates to the animal's appearance are reinterpretations of its lifestyle, such as radical proposals that *Spinosaurus* was a largely aquatic, swimming animal perhaps occupying a similar niche to the extinct species which eventually gave rise to whales (e.g. Ibrahim et al., 2014a, 2020a; Fabbri et al., 2022a). This view is by no means universally accepted (e.g. Henderson, 2018; Hone and Holtz, 2017, 2021; Sereno et al., 2022), and debates continue not only about how long *Spinosaurus* spent in the water, but also about fundamental details such as its basic proportions, overall size, and the shape of its sail (e.g. Hartman, 2020; Sereno et al., 2022).

In short, *Spinosaurus* keeps changing as a result of a fundamental paucity of fossil evidence, and its current interpretation is very unlikely to be final. Indeed, the debate around *Spinosaurus* prompted one of its leading experts, Nizar Ibrahim, to write that we 'should finally accept that there is no such thing as a 'final word' in dinosaur reconstructions, weight estimates and behavioral interpretations' (Ibrahim et al., 2014b). This is inarguable, but some words are more final than others: scientific interpretations and artistic impressions of *T. rex* – though they have changed considerably – have been comparatively fixed since the early, much more substantial, fossil discoveries of the 1900s.

Perhaps it is partly because it will not stay still, because there is so little bone to attach a reconstruction to, because it is almost fantastically strange, that *Spinosaurus* has had such a winding path to

its current status as a dinosaur celebrity. These and other factors may also explain why it has struggled to achieve *Tyrannosaurus*'s cultural footing as a dinosaurian household name despite some very focused efforts to attain or surpass *T. rex* in popularity. For even in relatively specialised publications, there has been little to say about *Spinosaurus* until recently. For instance, William Nothdurft's *The Lost Dinosaurs of Egypt*, a book-length popular history exclusively focused on Stromer's North African discoveries, of which *Spinosaurus* was by far the most charismatic, mentions the animal only on eight pages (Nothdurft et al., 2002). While the contention and lack of fossil evidence surrounding this species might tend some practitioners towards Hallett's position, it has certainly not prevented many writers, artists and scientists from attempting the 'pure fantasy' of a *Spinosaurus* reconstruction – as we will see in the next few sections, which run through the phases of the animal's public life in greater detail.

Discovery and early interpretations

The first and, for a long time, only bones referable to *Spinosaurus* were recovered during expeditions launched to the Egyptian Bahariya Formation by the Bayerische Staatssammlung für Paläontologie und Geologie (Bavarian State Collection for Palaeontology and Geology, whose public-facing museum is now the Paläontologisches Museum München) in the early twentieth century. Although Stromer's name has become most closely attached to *Spinosaurus* over time, its fossils were actually discovered in 1912 by Richard Markgraf, a long-term collaborator of Stromer's, and by other prominent palaeontologists who worked in various African nations (Nothdurft et al., 2002), to say nothing of the Egyptians and Syrians who performed the labour of packing and transporting the fossils. Stromer described and published illustrations of these in a 1915 paper which expressed his desire to reconstruct the entirety of the animal, but his efforts in this were frustrated by the outbreak of war across Europe. A second shipment of *Spinosaurus*-like bones awaited study in Egypt, held back by the authorities even from respected scientists like Stromer because of tensions and mistrust between Anglo-Egyptian and German governments. These fossils were eventually shipped to Germany in 1922 and described by Stromer in 1934. Along with the type, they formed the totality of Munich's *Spinosaurus* material when he summarised his thoughts on this animal in 1936.

While the First World War frustrated Stromer's work on *Spinosaurus*, the Second World War destroyed it outright. Despite Stromer's well-documented concern for safeguarding the Bavarian State collections against Allied bombing, the museum took no action to remove them (Northdurft et al., 2002). On 24 April 1944 the entire collection was destroyed during an Allied raid, excepting material previously smuggled away by concerned museum workers. The *Spinosaurus* fossils were among the casualties, leaving only the descriptions and illustrations published by Stromer, along with a few then-unpublished photographs (Smith et al., 2006), as evidence of their existence.

Needless to say, the destruction of the original and only-known *Spinosaurus* fossils was surely a major factor in the initial obscurity of this animal on the public stage, but it is probably not the only reason *Spinosaurus* remained out of the public eye in its early history. The early twentieth century was a golden era for the promotion of vertebrate palaeontology (Witton, 2018; Nieuwland, 2019; Rieppel, 2019; Manucci and Romano, 2022) and German scientists and artists, despite the political turmoil they lived through, were very active in the reconstruction and promotion of dinosaurs. Notable events included radical reposing of dinosaurs in German museums (see Nieuwland, 2019), Othniel Abel's first major review and critique of palaeoart theory and methods in 1925, and the Berlin aquarium's murals, friezes and statues of iconic prehistoric species designed by Heinrich Harder (Lescaze, 2017; also mentioned by Nieuwland in this volume). *Spinosaurus*, a giant and most atypical predatory dinosaur ripe for public interpretation, had been announced during a rich period of popularised palaeontology and had a window of two or three decades to gain wider attention before its type material was obliterated.

We posit that Stromer himself may have played a role in keeping *Spinosaurus* out of the public eye. As an aristocrat with private means, Stromer had no need to pursue the funding avenues opened up by mass publicity and, moreover, the Bavarian State Collection was more focused on education than popularisation. Stromer was also sceptical of the value of palaeoartistic reconstructions, especially where they were based on poor fossil material (Stromer 1934, 1936). His views were not as extreme as those of some nineteenth-century palaeoart critics (see Witton and Michel, 2022) and he did publish reconstructions of extinct taxa, but his approach was a cautious and meticulous one. He wrote in 1915 that he would not attempt to reconstruct *Spinosaurus* before the additional fossil material held in Egypt had been analysed (Stromer, 1915: 28–9) and, when he did oversee illustrations of restored bones or skeletons,

he provided extensive footnotes justifying their appearance, explaining their measurements and noting sources of reference (e.g. Stromer, 1936: 68, on *Carcharodontosaurus*; also see below). We might directly contrast this with a more publicity-hungry scientist, like the American Museum of Natural History's Henry Fairfield Osborn, who had *Tyrannosaurus* named and reconstructed in both skeletal and fleshed-out illustrations before its type specimen was even fully prepared from its rock matrix (Osborn, 1905). As a response to W. E. Swinton's well-illustrated 1934 textbook, *The Dinosaurs: A short history of a great group of extinct reptiles*, Stromer stated plainly in 1936 that 'skeletal reconstructions are made too lightly, even from very poor finds, and published speculations about [dinosaur] lifestyle are based on rather vague analogies' (Stromer, 1936: 62, our translation).

With all this in mind, it is perhaps surprising that Stromer made any effort to reconstruct the poorly-known *Spinosaurus* at all. He did, however, follow up his 1915 desire with a guarded attempt at visualising the *Spinosaurus* skeleton in 1936. Working with a colleague who executed the drawings under his guidance (a Dr Erhardt, whose first name is unknown to us), Stromer had several hesitations about this endeavour, including concerns about the scant material and the errors that would arise from reconstructing *Spinosaurus* from more than one individual. He persisted, however, because he felt it was important to visualise the bizarre and unprecedented *Spinosaurus* sail. He wrote:

> Despite such misgivings [about reconstructing extinct animals], I believe I must have some reconstructions of Theropoda drawn by Dr. Erhardt according to my information. In *Spinosaurus aegyptiacus* […] this is very daring due to a lack of knowledge of the skull and extremities, but this is the only way to visualise its strange dorsal spine processes, and after all there are quite a number of different parts of one individual. Of course, a lot is hypothetical. (Stromer, 1936: 63–4, our translation)

The Erhardt illustration referred to here is the first reconstruction of a *Spinosaurus* skeleton. It was necessarily chimeric, blending elements of *Gorgosaurus* and *Tyrannosaurus* with *Spinosaurus* fossils to visualise a gigantic and spectacular predatory dinosaur (Stromer, 1936) (Figure 4.4). But Stromer was as meticulous with finer details as his *Spinosaurus* fossils allowed, estimating the sizes of partially known elements, using teeth to predict the depth of the upper jaw and carefully considering the order of the sail vertebrae. These concerns led to several commendable

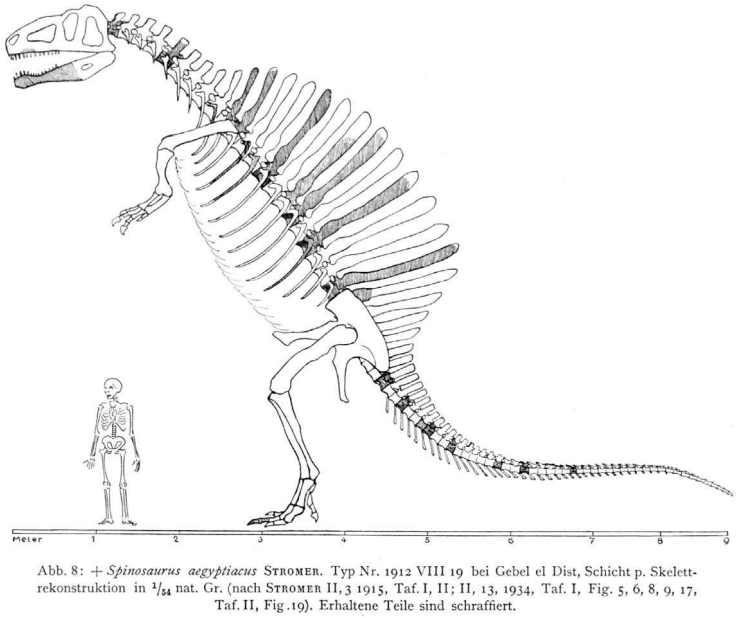

Abb. 8: + *Spinosaurus aegyptiacus* Stromer. Typ Nr. 1912 VIII 19 bei Gebel el Dist, Schicht p. Skelettrekonstruktion in $^1/_{54}$ nat. Gr. (nach Stromer II, 3 1915, Taf. I, II; II, 13, 1934, Taf. I, Fig. 5, 6, 8, 9, 17, Taf. II, Fig. 19). Erhaltene Teile sind schraffiert.

Figure 4.4 Erhardt's speculative skeletal illustration, published by Stromer (1936), the first effort at reconstructing the appearance of *Spinosaurus aegyptiacus*. Image in public domain, obtained from Biodiversity Heritage Library.

insights, such as a long torso and short legs, both of which are still thought to characterise *Spinosaurus* today (e.g. Ibrahim et al., 2014a, 2020a; Hartman, 2020; Sereno et al., 2022).

It seems that Erhardt's drawing was destined for technical literature alone and was not used to communicate information about extinct life with the public in publications or (it appears) museum exhibits (Smith et al., 2006). While other early twentieth century museums competed to build the most dramatic and lifelike displays of fossil animals and had vivacious life reconstructions executed by skilled artists (Brinkman, 2010; Rieppel, 2019), the Paläontologische Staatssammlung München displayed its *Spinosaurus* fossils modestly, with no apparent effort at representing the complete animal (Smith et al., 2006). Little is known of the circumstances surrounding the Munich *Spinosaurus* mount, and we cannot rule out practical limitations associated with displaying these large bones in a lifelike configuration, but displaying the fossils in a case without any real indication of its whole-body appearance certainly fits Stromer's documented attitudes towards palaeontological representation.

It may be wondered why, if Stromer had so many reservations around restoring and promoting *Spinosaurus*, other agents did not step in to do it for him. After all, no-one 'owned' the concept of *Spinosaurus* and there would be nothing to stop others from writing about and illustrating it. Nationalism and institutional interests may have played an important role here. The 'golden era' of publicising vertebrate palaeontology outlined above was not a magnanimous global celebration of extinct life but the result of self-aggrandizing, competing scientific institutions promoting their own brand of palaeontological science (Brinkman, 2010; Rieppel, 2019; Nieuwland, 2019). Museums constructed their publicity in line with their own achievements and collections in a way that dissuaded focus from unsung discoveries in other research institutions. The Paläontologische Staatssammlung München was, indeed, an outlier for being so reserved. Other German institutions, such as the Museum für Naturkunde Berlin, saw value in promoting their work on '*Brachiosaurus*' *brancai* (now *Giraffatitan brancai*) and '*Naosaurus*' (on which see Ilja Nieuwland's chapter 'A good officer. The Long and Remarkable Career of the Chimaeral *Naosaurus*'). American museums, meanwhile, were so successful at promoting their dinosaur studies that the twentieth-century dinosaur 'canon' became dominated by North American animals. Thus, the exploits of the Munich researchers – a small and academic-focused unit working on the other side of the world – may have seemed not only irrelevant to these institutions but even potentially a threat to their own PR efforts. One of the most prominent institutional voices in early-twentieth-century palaeontology, the American Museum of Natural History, was deeply invested in portraying *Tyrannosaurus* as the largest, most formidable predatory dinosaur of all time (Witton, 2025) and, fragmentary as it was, *Spinosaurus* clearly challenged the tyrant king in raw size (Stromer, 1936). Such conflicts of interest and the need to present an 'institutionally compliant' version of prehistory may have actively or passively shaped the early lack of interest in *Spinosaurus*, even if that meant ignoring some truths of contemporary knowledge.

Mid and late twentieth century

Following the destruction of the Munich *Spinosaurus* fossils in 1944, only Stromer's descriptions and illustrations of the *Spinosaurus* bones evidenced the existence of this species. Its ghostly scientific presence was mirrored in anglophone popular culture, where it remained relatively obscure despite its size and spectacular appearance. When mentioned,

such as in vertebrate palaeontology textbooks, it was invoked primarily to discuss its unusual vertebrae (e.g. Romer, 1933; Swinton, 1934, 1970). Restorations of its life appearance remained rare and may not have appeared until 1962, when a flesh reconstruction featured in the educational comic *Young Earth*, itself published within the series *Turok: Son of Stone*. *Young Earth* introduced palaeontological topics via a traditional comic format and fleetingly showed *Spinosaurus* in *Turok* issue 29, within the story titled 'Coming of the Flesh Eaters' (see Figure 4.2). This was a strange volume for *Spinosaurus* to make its life restoration debut, as *Turok*'s prehistoric animal depictions were almost universally copies of familiar and famous palaeoartworks by Rudolph Zallinger, Charles Knight, Neave Parker and others, rather than novel reconstructions. This may explain why the *Turok Spinosaurus*, drawn by comic artist Rex Maxon, is a small and simple drawing restricted to one panel. Looking like a modified version of Neave Parker's c. 1960 *Megalosaurus*, it differs so sufficiently from Stomer's consideration in overall proportions, in the extent of the spinal processes, and in lacking soft-tissue between the sail spines (something hypothesised, though not illustrated, by Stromer, 1915) that we suspect it was based more on textbook descriptions rather than the 1936 skeletal illustration. Though it seems irregular for a children's comic to produce the first flesh reconstruction of a dinosaur, the episode foreshadows the far more prominent role that popular media would eventually have in popularising *Spinosaurus*.

After *Turok*, the presence of *Spinosaurus* in popular media began to increase throughout following decades, and by the end of the twentieth century it had become a semi-regular feature in popular dinosaur books. Its sail remained a chief catalyst for popular interest, but its size and status as an African dinosaur also drew the attention of authors and illustrators. By this time, its gigantic stature was well known: estimates put *Spinosaurus* at 15 m long (Glut, 1982), a value that compared well to the first length estimates of *Tyrannosaurus* (e.g. Osborn, 1912) but not to mid-twentieth century revisions that had shortened the *T. rex* tail by 4 m (Newman, 1970). Following these, *T. rex* was now smaller than *Spinosaurus* at 'only' 11 or 12 m in total length, although this did nothing to displace it as a hugely popular dinosaur.

Two illustrations from the mid-twentieth century would define the appearance of *Spinosaurus* until the end of the 1990s: a second skeletal reconstruction published in Theodore E. White's 1967 *Dinosaurs – At Home*, and Giovanni Caselli's painting of a *Spinosaurus* eating the end of a sauropod tail, published in L. B. Halstead's influential 1975 book *The Evolution and Ecology of The Dinosaurs* (see Figure 4.2). The former

has little of the precise anatomical consideration exhibited by Stromer (1936), presenting *Spinosaurus* as a *Tyrannosaurus* with a sail and a three-fingered hand. Copies (sometimes slightly edited) of this illustration appeared in subsequent works (e.g. Boneparte, 1978; Case, 1982) and were probably the bases for several long-legged, three-fingered life restorations in popular works (Burton and Dixon, 1984; Lambert, 1990) and newly emerging *Spinosaurus* toys. Caselli's artwork, in contrast, was seemingly influenced by the 1936 skeletal in showing *Spinosaurus* with four fingers, a long torso and shorter legs. This painting was the first of a parallel strain of *Spinosaurus* depictions which, through referencing Caselli – or Stromer (1936) – contrasted with White's long-legged, *T. rex*-like version (e.g. Moody, 1977; Glut,1982; Norman, 1985). Another brief appearance in a comic, this time *2000 AD*'s science fiction story *Flesh*, added a pulp quality to a Stomer-esque vision of *Spinosaurus* in 1977.

While *Spinosaurus* eventually found attention among dedicated dinosaur fans, it lacked traction in other quarters of professional palaeontology. Little research was conducted on it – hardly surprising, given the absence of fossils to study – and it remained untouched by the most influential artists of the early- and mid-twentieth century, such as Charles Knight, Rudolph Zallinger, Zdeněk Burian and Neave Parker. This artistic boycott extended to the palaeoartists closely associated with the Dinosaur Renaissance, such as Gregory S. Paul, Ely Kish, Douglas Henderson, and Mark Hallett who – as noted above – regarded it as too poorly known to attempt a reconstruction. Leading late twentieth-century palaeoartists embraced scientific rigour and prioritised understanding animal anatomy through substantial fossil remains, a view that required meeting certain informational thresholds before a dinosaur's life-appearance could be restored. In contrast with earlier high-profile fossil reconstructions, it was now felt that one could not rationalise the anatomy of a whole animal with just a few bones (e.g. Czerkas and Olsen, 1987a, b). In his seminal *Predatory Dinosaurs of the World*, Paul (1988) echoed Hallett's reservations, lamenting the inability to restore *Spinosaurus* in his catalogue of reconstructed theropod skeletons. To our knowledge, the scepticism surrounding restorations of *Spinosaurus* at this time meant that, among the big names in palaeoart of this era, only a few, including John Sibbick and William Stout, attempted the feat (Glut, 1982; Norman, 1985), both seemingly basing their work on Stomer's 1936 restoration. Without further information, *Spinosaurus* seemed unrestorable to science-focused artists, and would remain so until more fossils of it, or at least of a close relative, were unearthed.

The battle for the big screen

Whatever profile *Spinosaurus* had attained by the approach of the twenty-first century, it was developed without vested interests in its status. Its inclusion in books and toy lines was always as part of efforts to show Mesozoic dinosaur diversity at its fullest and it was never, by itself, a focal point. But as the end of the twentieth century approached, this situation changed. New fossil discoveries catalysed more research into *Spinosaurus* itself and permitted more informed, if admittedly still far-reaching, reconstructions, transforming *Spinosaurus* from a species known only to dinosaur devotees to one that could take a commanding position in popularised palaeontology.

This transformation began with radical developments in spinosaurid dinosaur research during the 1980s and 1990s. New spinosaurid species that were represented by relatively complete skeletons, *Baryonyx walkeri* (Charig and Milner, 1986, 1997) and *Suchomimus tenerensis* (Sereno et al., 1998), were unearthed and dramatically changed views of spinosaurid anatomy, augmented by less complete but nevertheless important fossils (Martill et al., 1996; Kellner and Campos, 1996; Russell, 1996; Sues et al., 2002). Possible new *Spinosaurus* material was also identified at this time from across Northern Africa, ultimately marking a shift in consideration of *Spinosaurus* as a traditionally Egyptian animal to one more routinely found in the Kem Kem beds of Morocco (Bouaziz et al., 1988; Buffetaut, 1989, 1992; Russell, 1996; Taquet and Russell, 1998). Among these remains was purported evidence of a second *Spinosaurus* species, *S. maroccanus* (Russell, 1996; Taquet and Russell, 1998), although the validity of this was disputed (as remains the case for virtually all North African spinosaurid material; we return to this subject later).

The glut of new spinosaurid fossils revealed that these dinosaurs were far from the *T. rex*-like creatures of earlier reconstructions. They had long, narrow snouts, tall dorsal vertebrae and stout, strongly clawed forelimbs. Much was made of the superficially-crocodylian nature of their skulls, and a number of lines of evidence, including functional studies and fossilised gut remains, hinted at a diet that included fish as well as other dinosaurs (e.g. Charig and Milner, 1986, 1997; Buffetaut, 1989; Sereno et al., 1998; Holtz, 1998). In spite of the new remains referred to it, the anatomy of *Spinosaurus* remained enigmatic, but the close kinship of this species with *Baryonyx* and *Suchomimus* – the species Billy mistakes *Spinosaurus* for in *Jurassic Park III* – implied that a bold reimagining was in order: *Spinosaurus* was probably a gigantic, sail-backed dinosaur with a superficially crocodile-like face and large, powerful arms.

Spinosaurus was thus primed for reinvention, and its status as the biggest of a newly recognised, visually distinctive group of dinosaurs gave it potential candidacy for prehistoric celebrity. Interest in these developments was not confined to academics, but also included Hollywood producers looking for a new dinosaur face for the flagship franchise of palaeontological cinema *Jurassic Park*. Production on a third *Jurassic Park* film had begun in the late 1990s and, after two *Tyrannosaurus*-dominated entries, the series was actively looking for a new predatory dinosaur antagonist (Universal Studios Home Video Inc, 2001a). Perhaps on account of their distinctive anatomy, a spinosaurid was chosen as the new dinosaur lead, and the film entered preproduction with the intent of making *Baryonyx* its new villain (Universal Studios Home Video Inc, 2001b). This was soon replaced, however, by the gigantic *Spinosaurus*, seemingly with little concern regarding its obscure status – perhaps this was even an asset. Facing their third film of dinosaurs chasing people around tropical islands in less than a decade, *Jurassic* filmmakers were looking for ways to surprise and excite audiences enough to draw them back to cinemas for another dinosaur adventure (Universal Studios Home Video Inc, 2001a). In doing so, they would transform a dinosaur whose biggest pop-cultural moment had hitherto been single panels in decades-old comics into a major force in modern palaeontological media.

In 'behind the scenes' features and articles promoting the film, the *Jurassic Park III* production team speak openly about the challenges of replacing *Tyrannosaurus*. The creative angle seemed to be that *Spinosaurus* must dominate everything within and around the film to prove its worth as the series' new primary antagonist. The film goes to great efforts to show that *Spinosaurus* is no mere *Tyrannosaurus* substitute but a transcendence to the next level of dinosaur mayhem – the greatest prehistoric threat yet seen. Quite apart from defeating a *T. rex* in battle, *Spinosaurus*'s activities frequently and perhaps deliberately subvert the capabilities of *Jurassic Park*'s earlier star. Where *Tyrannosaurus* in the first movie was frustrated by attempting to reach humans in vehicles, *Spinosaurus* removes the front of a plane and eats people trapped inside. While metal fences proved obstacles for *Tyrannosaurus* (at least temporarily), *Spinosaurus* charges through a larger, stronger-looking barrier without injury. And where the arms of *T. rex* are famously small and of questionable effectiveness, *Spinosaurus* uses its own front limbs to grip objects, support its weight and swipe at enemies. This is emphasised with shots that show every component of *Spinosaurus* in an aggressive or menacing light, its sail even rising like an ominous shark fin during a swimming sequence. *T. rex* is not even

given the dignity of challenging the franchise newcomer at the film's climax: it dies early, as mentioned above, and it is the humans, with their fire, who must drive *Spinosaurus* away.

Despite wanting a wholly new antagonist, the *Jurassic Park III* filmmakers seemingly ignored much of the then-new data on spinosaurid anatomy, and created a *Spinosaurus* that blended attributes of *Baryonyx* and *Suchomimus* with *Tyrannosaurus* (see Figure 4.2). While its head was relatively accurate to spinosaurid fossils, its body, neck and tail are overly short, and its limbs are overly long. The hands also possess three large claws, instead of the single large thumb claw and two smaller claws of real spinosaurids. Most egregiously, the sail is also only a loose approximation of the structure hinted at by Egyptian fossils, differing in the angle of the vertebral spines (a common mistake in virtually all *Spinosaurus* restorations up to this point), size (it is much smaller than it should be), and overall shape (a low gentle arc rather than the tall, sub-rectangular structure predicted by Stromer and subsequent researchers). Little is also made of the likelihood that fish made up a portion of spinosaurid diets, the aforementioned swimming sequence surely owing as much to the yet-unadapted river scene in the first *Jurassic Park* novel, as any allusion to piscivorous habits. The vaguely crocodilian motif that extends across the skin design is a further departure from the reality of dinosaur biology captured in earlier *Jurassic Park* films, the *Spinosaurus* having noticeably rough, large scales rather than fossil-accurate small, polygonal ones. This pseudo-crocodylian morphology is reinforced by a recurring gag where a phone swallowed by the *Spinosaurus* rings from its digestive tract, recalling the clock-swallowing crocodile that plagued Captain Hook (our thanks, for this point, to Jordan Kistler).

Collectively, these creative choices subtly tip the *Jurassic Park Spinosaurus* from an interpretation of a real animal into the realm of 'movie creature'; specifically, an especially nightmarish, exaggerated version of the tyrannosaurs that antagonised the human characters in previous films. And yet, the filmmakers promoted their take on *Spinosaurus* as both naturalistic and even educational, the famous special effects creator Stan Winston opining that audiences learn something about dinosaurs simply by watching *Jurassic Park* movies (Universal Studios Home Video Inc, 2001a). This seemingly conflicts with an in-film conversation about the realities of the *Jurassic Park* dinosaurs, however, which are described as 'theme park monsters' and thus not the same entities as the fossilised forms excavated from sedimentary rocks (on the wider issue of the first film's relationship with scientific orthodoxy, see Fallon and Hone's chapter in this volume). The friction between following

and sensationalising science that has existed in, and been dramatised by, all *Jurassic Park* films is perhaps especially obvious in these conflicts. The liberties taken with *Jurassic Park III*'s 'theme park' version of *Spinosaurus* can be seen as the first major step in the franchise's progression towards the wholly fictitious, thoroughly-monsterised dinosaur creatures of later entries, such as '*Indominus rex*' in *Jurassic World* (2015) and '*Indoraptor*' in 2018's *Jurassic World: Fallen Kingdom*.

Released to lukewarm critical responses and an underperforming box office, *Jurassic Park III* was the last *Jurassic* film for more than a decade. Critics felt that this third *Jurassic* film brought little to the series despite its new star and, worse, that the concerted efforts to subvert *T. rex* as the ruler of dinosaur cinema had fallen short. *Empire* concluded that 'the much-mooted spinosaurus [sic] fails to usurp the T-rex as Godfather of the dinosaur' (Errigo, 2001). *Variety* wrote that the 'lumbering spino, despite its larger size, longer jaw and fancy back fin, just doesn't cut it as a substitute T-Rex', further noting that 'this new addition to Winston's dino lineup looks more like an escapee from a Japanese monster movie' (Elley, 2001). This latter comment adds a prophetic edge to Hallett's (1987) concerns about the 'pure fantasy' of restoring *Spinosaurus* and implies that, despite *Jurassic Park III*'s claims to scientific accuracy, even mainstream audiences have some sensitivity to monsterised, exaggerated movie dinosaur depictions. A minority of reviews did speak up for poor *Spinosaurus* (*Rolling Stone* considered it 'badass' (Travers, 2001)), but its rejection by critics and, judging by box office receipts, the wider public, saw the *Jurassic* franchise abandon *Spinosaurus* in the more recent films. Its only subsequent appearance is as a skeleton (albeit one that is notably different from the *Jurassic Park III* design) on the main street of the theme park in 2015's *Jurassic World*.

It is difficult not to see the reduction of *Spinosaurus* to set-dressing, as an acknowledgement of the animal's pretender status to the *Tyrannosaurus* throne. In a series renowned for its lifelike dinosaur effects, and in a theme park where dinosaurs are literally brought to life, is there a greater shame than only being represented by a skeleton? That this osteological cameo is a response to the hubris of replacing *T. rex* is left in no doubt when, at the film's climax, a freshly unleashed *Tyrannosaurus* (the same individual seen in the iconic first *Jurassic Park*) literally crashes through it, effortlessly reducing its former foe to a pile of broken bones. Paltry as it seems in this context, of course, a complete *Spinosaurus* skeleton – even smashed – would of course be a dream come true for any real-life dinosaur scientist.

Spinosaurus 3.0

It is testament to the influence of the *Jurassic* series that its underperforming, single-film flirtation with *Spinosaurus* could nevertheless change the shape of popularised palaeontology. The initial run of *Jurassic* films may have been finished with *Spinosaurus*, but *Jurassic Park III* sowed seeds which grew the cultural cachet of *Spinosaurus* enormously throughout the 2000s. Its days as an obscure species known only to dinosaur fans and experts were in the past, as it now became not only included in dinosaur products, but could be used to sell them. *Spinosaurus*, often in a guise strongly reminiscent of its *Jurassic Park* appearance, appeared on the covers of books, became a much more common toy and model in dinosaur parks, and even headlined documentary series such as Discovery's sensationalist *Monsters Resurrected* (2009) and the BBC's more grounded, science-focused *Planet Dinosaur* (2011) (see Figure 4.2). Artists even sculpted *Spinosaurus* skeletons for special museum exhibits, such as that featured in the Gunma Museum of Natural History, Japan, in 2010 (Figure 4.5). *Spinosaurus* had failed to gain widespread acceptance from the cinema-going public, but it had established itself as a new, exciting face for science-focused entertainment and merchandise.

Scientific interest in *Spinosaurus* paralleled that of popular culture as research on it continued to gain pace in the early twenty-first century. With spinosaurids now generally better understood, attention shifted to not only reporting more fragmentary remains of Moroccan *Spinosaurus* (Dal Sasso et al., 2005) but to better understanding its size and ecology (e.g. Dal Sasso et al., 2005; Therrien and Henderson, 2007; Cuff and Rayfield, 2013). Perhaps thanks to the name recognition brought by *Jurassic Park III*, some of these studies were deemed newsworthy, especially if they demonstrated that *Spinosaurus* was larger or somehow more intimidating than *Tyrannosaurus* (e.g. Hecht, 2006). Here, the competition initiated by *Jurassic Park III* to justify their use of *Spinosaurus* as a movie monster was being put to different use: validating the importance of scientific research and outreach.

Competition with *T. rex* was incorporated into another large-scale media event surrounding *Spinosaurus* in 2014 – the *National Geographic* cover story with which this chapter began. Here, a new scientific paper (Ibrahim et al., 2014a) was the nucleus of a coordinated media extravaganza. The paper itself focused on the discovery of FSAC-KK 11888, a new partial skeleton of *Spinosaurus* discovered in Morocco during the early 2010s, described in the prestigious journal *Science*.

Figure 4.5 Skeletal mounts of *Spinosaurus*. [A] long-legged reconstruction at Gunma Museum of Natural History, Japan, in 2010, photo by Kabacchi, CC-BY 2.0 [B] shorted-legged, aquatic interpretation based on Ibrahim et al. (2014a) at the National Geographic Museum in Washington DC, 2014, B, photo by Ryan Somma, CC-BY 2.0.

Using this material, Ibrahim et al. presented a radically new perspective on *Spinosaurus* with a totally revised skeletal restoration characterised by remarkably short hindlimbs and an 'M'-shaped sail (Figures 4.2, 4.5b and 4.6a), a suggestion that it was a knuckle-walking quadruped when

on land but a proficient swimmer in water, and a bold taxonomic proposal that incorporated much of North Africa's spinosaurine material into the *S. aegyptiacus* species. They also suggested that their new specimen, a partial skeleton incorporating hindlimb, pelvic and vertebral material, should be considered the neotype of *Spinosaurus aegyptiacus*, finally giving *Spinosaurus* a type specimen after the destruction of the original 70 years earlier.

This daring new interpretation of *Spinosaurus* was matched in scale by a tie-in media effort. Along with the 2D palaeoart and online coverage commensurate with modern high-key palaeontological papers was a television documentary, the front cover and key article space in October 2014's issue of *National Geographic*, and a touring exhibition featuring newly crafted, life-size flesh and skeletal reconstructions of *Spinosaurus* (see Figure 4.5b). As was now standard, the rivalry between *Spinosaurus* and *Tyrannosaurus* was a headline focus.

For all this use of a familiar angle, the extravagance and evident investment in this PR effort was unusual. It surely ranks as one of the most ambitious events ever to promote a new piece of dinosaur research, almost recalling the promotion of blockbuster movies or prestigious sports events, more than routine public scientific communication. With media hype of this scale, the boundaries between the dinosaur awareness campaign run by *Jurassic Park* and one run by *National Geographic* are more blurred than ever. Though the comparison is a complex one in many respects, we observe here that whatever the intentions behind both episodes, many of their techniques – and perhaps their attitudes to palaeontology – are very similar. Both capitalised on a romanticised ideal of adventurous palaeontological fieldwork in exotic locations, both sought to marvel and entertain with sensational dinosaur science, both employed leading-edge artistry to bring their stories to life, and both saw the same potential in dramatically reinventing a poorly understood but spectacular predatory dinosaur. Most significantly, both were prepared to invest heavily in their respective interpretations of *Spinosaurus* despite the still-developing science around the dinosaur itself.

Further echoing *Jurassic Park III*, *National Geographic*'s coverage takes an authoritative stance on *Spinosaurus*'s new guise. Any concerns about final accuracy are invisible in the abundant media surrounding Ibrahim and colleagues' new study and, outwardly at least, this looked to be a definitive take on this peculiar theropod. As it proved, though, the science fuelling this media extravaganza was highly controversial. Within days of its publication, academics and popular science writers penned articles expressing varying degrees of scepticism around just about every

major claim made by the paper (e.g. Barrett, 2014; Black, 2014; Hartman 2014a, b) and follow-up studies provided more thorough criticisms and different interpretations shortly thereafter (e.g. Evers et al., 2015; Hendrickx et al., 2016; Henderson, 2018; Hone and Holtz, 2017). These attacked the very foundations of this new vision of *Spinosaurus*, including its new short-legged proportions, its competence as a swimmer, and the proposal of replacing the lost Egyptian type specimen with new remains from Morocco. The latter ties into complex issues about the identities of North African spinosaurid fossils and the question of whether the new Moroccan material – including the specimen at the heart of the *National Geographic* campaign – should really be identified as the Egyptian *Spinosaurus aegyptiacus* (Evers et al., 2015). Ibrahim et al. countered these criticisms, both online and in print (Ibrahim et al., 2014b, 2020a; Fabbri et al., 2022b), but it remains to be seen whether these controversies have been fully resolved.

Despite the academic backlash, the 2014 Ibrahim et al. vision of *Spinosaurus* went on to be enormously influential. Not only is the current era of *Spinosaurus* science framed by this study (as we go on to discuss) but pop-culture extensions of palaeontological science openly embraced their distinctly short-legged, semi-aquatic reconstruction. *Spinosaurus* now swims through popular dinosaur books, toy chests and model display cabinets in pursuit of fish, like a sail-backed crocodilian, pushing out *Jurassic Park*'s long-legged 'superpredator' in many, though perhaps not all, avenues of popular publications and merchandising. And yet, further changes awaited even this relatively recent reinvention.

More fossils, more controversy

A mere six years after their much-publicised research, Ibrahim et al. (2020a) presented another transformative study which dramatically altered *Spinosaurus*'s appearance yet again (Figure 4.6a). This time, additional material from a return to the Saharan dig site yielding the 2014 specimen showed an extraordinarily deepened tail formed from elongate, slender vertebral spines and mirroring chevron bones. This unprecedented dinosaurian tail, the team argued, was a paddle-like organ that could be sculled like the tail of a crocodilian to drive a swimming *Spinosaurus* through water. Coinciding with the study's appearance in the prestigious journal *Nature*, a second media blitz followed that included an abundance of high-quality artwork, animations, another dedicated feature in *National Geographic*, and the production of more life-sized

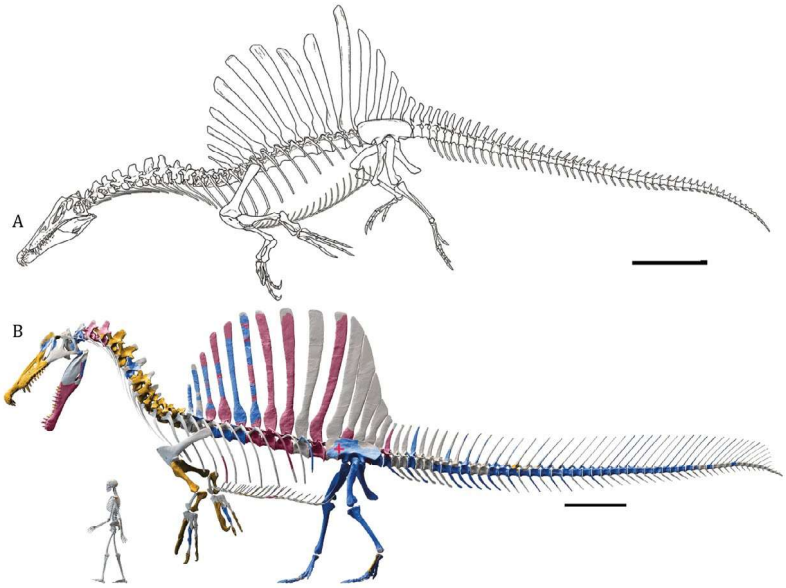

Figure 4.6a Interpretations of *Spinosaurus aegypticus* skeletal anatomy from the last decade, also showing contrasting interpretations of lifestyle. A, reconstruction based on data from Ibrahim et al. (2014a), showing *Spinosaurus* as an aquatic, swimming animal – the expanded tail was yet to be discovered.
Figure 4.6b The most recent reconstruction of *Spinosaurus* published at time of writing, from Sereno et al. (2022), showing the new tail described by Ibrahim et al. (2020a) but also a terrestrial, standing pose, reflecting the hypothesis of non-aquatic habits preferred by these authors. The varying hues show reference material used in the reconstruction: blue, FSAC-KK 11888; red; the destroyed *Spinosaurus* holotype; yellow; other remains referred to *Spinosaurus*. Scale bars represent one metre. A, from Ibrahim et al. 2020b, CC-BY 4.0; B, from Sereno et al. (2022), CC-BY 4.0.

restorations for museum display (Greshko, 2020). Though not quite on the same level as the 2014 media campaign, this was still a bombastic, show-stopping press event that leaves little doubt about the status of *Spinosaurus* among popularisers of science.

It wasn't only a high level of public interest which recalled the 2014 publicity: the new paper sparked further controversy among dinosaur workers who doubted the interpretation of the new tail as a swimming aid. Hone and Holtz (2021), in their analysis of *Spinosaurus* anatomy, concluded that the tail was a display structure, not a swimming aid, and

that *Spinosaurus* would have found prey more like a giant heron than an aquatic pursuit predator. More data has been added to the debate in the form of spinosaurid bone density, which Fabbri et al. (2022a) argue points again to a specialist aquatic lifestyle, but others feel does not substantially challenge the heron-like model (Myhrvold et al., 2022; Sereno et al., 2022). Researchers are still unable to reach a conclusion on the proportions and appearance of *Spinosaurus*: Sereno et al. (2022) argue that Ibrahim et al. have made it too long in the chest and arm, while also challenging the M-shaped sail with a more traditional interpretation (Figure 4.6b).

Thus, almost a hundred years after Stromer's first tentative efforts at a restoration, and despite being equipped with much more fossil data, the ability to reconstruct *Spinosaurus* remains heavily dependent on inference. If anything, it seems the more researchers learn about *Spinosaurus* the more controversial it becomes, raising interesting questions about its status as a modern superstar dinosaur species.

Discussion: unspinning *Spinosaurus*

To think about the history of *Spinosaurus* is inevitably to think about how the popularity of an extinct animal is governed by interactions between evidence, imagination and the agency of individuals and institutions. Is it because of a lack of fossils that there was relatively little interest in *Spinosaurus* in the twentieth century, or is it because of the lack of interest that the fossils took so long to find? How much were attitudes regarding *Spinosaurus* shaped by Stromer's conversative views on reconstructing and promoting dinosaur discoveries? The history of this unusual and controversial dinosaur demonstrates how tangles of circumstance and interaction between different agents, each with their own goals and attitudes, shape mainstream interest in prehistoric life.

Particularly in its first century, *Spinosaurus* shows how individual philosophies can lead to thoroughly contrasting opinions of a dinosaur's role in popular culture. Remarkable as it seems, Stromer's cautious technical reconstruction is cut from the same cloth as the bombastic *T. rex*-destroying *Spinosaurus* of *Jurassic Park III*: both are based on largely the same fossil data and yet the confidence and impact of their restorations could not be more different. This distinction in approach does not simply reflect the discrete goals of a scientist and film company either, for it was palaeontologists who initially lifted *Spinosaurus* from purely academic literature and presented it in more accessible, popular venues (e.g. Swinton, 1934; White, 1967; Halstead, 1975). This

case illustrates the difficulty of drawing a firm line between 'science communication' and 'entertainment' when thinking about how dinosaurs move through popular culture. Though clearly taking liberties with the animal's appearance and behaviours, *Jurassic Park*'s intervention is not devoid of educational impact either in its intentions or its after-effects. The consensus is that it was instrumental in updating the public image of dinosaurs to incorporate key ideas from the Dinosaur Renaissance. *National Geographic*, meanwhile, no stranger to bombastic publicity and a part of the Disney empire since 2019, has clearly embraced the sensational tone set by Hollywood alongside the serious – if controversial – scientific publications on which it reports.

This is not to say, however, that *Spinosaurus*'s ascendency to mainstream popularised palaeontology has been determined entirely by a few influential agents. It seems fair to describe its initial, mid-twentieth century popularisation as relatively low-key: a product of book and comic authors deciding that *Spinosaurus* was remarkable enough to incorporate into the canon of popularised prehistory. There may have been several independent 'adoptions' of *Spinosaurus* into non-academic literature. After its first, unillustrated mention in a textbook (Swinton, 1934), it appears in three unique reconstructions: the peculiar illustration in *Turok*, as a high-spined *Tyrannosaurus* presented by White (1967), and finally Caselli's Stomer-based illustration in Halsted's 1975 *Ecology and Evolution of the Dinosaurs*. The differences between these images are so great as to suggest minimal or no cross-fertilisation of reference material and imply communal, rather than individual, recognition of *Spinosaurus* as an especially noteworthy dinosaur species. Because popular interest in *Spinosaurus* post-dated the late-nineteenth/early-twentieth-century origin of 'Dinomania', this communal adoption tells us little about what makes dinosaurs *as a group* interesting to the public, but it does tell us something about why some dinosaurs are considered more interesting than others. Even with only a portion of its anatomy known, the qualities of *Spinosaurus* – a gigantic, Egyptian reptilian predator with an aberrant sail taller than an average person – were enough to single it out as unique and strange, and thus worthy of mention and speculative illustrations. This implies that our depth of scientific understanding is of less importance to the popularisation of dinosaurs than the superficial quality of being somehow distinctive, be it anatomically, geographically or ecologically. (See, for a complementary perspective on this point using Mesozoic mammals, Elsa Panciroli and Chris Manias' chapter in this volume on 'Mammals, the measure of success? The legacy of 'progress' in natural sciences.')

The discussion of *Spinosaurus* as a unique dinosaur raises Stromer's century-old question about its restorability. This not only echoes the concerns about reconstructing extinct animals aired during the earliest decades of palaeontological science (Witton and Michel, 2022) but also broader, contemporary observations on the 'medialisation' of science as a whole (e.g. Weingart, 1998). Without doubt, recently discovered *Spinosaurus* fossils show that Stromer and, later, Hallett and Paul, were correct to doubt our ability to restore *Spinosaurus* from fossils discovered in the early twentieth century. These, it has emerged, only hinted at the bizarre anatomy of *Spinosaurus*. But substantial questions remain about even our most current restorations, from the shape of the sail to the proportions of the body (Hartman, 2020; Sereno et al., 2022), and these stand in contrast to the confidence of and investment in twenty-first century *Spinosaurus* depictions. Two of the three major iterations of *Spinosaurus* in the last two decades – *Jurassic Park III* and the 2014 Ibrahim et al. reinterpretation – were shown as inaccurate relatively quickly after their unveilings, undermining the definitiveness and authority implied by their tremendous hype and media reach. These could be seen as echoes of other grand exercises in dinosaur popularisation, not the least being the dinosaur sculptures created for the Crystal Palace Park's Geological Court in the mid-nineteenth century. As with twenty-first century *Spinosaurus*, the Crystal Palace recreations resulted from private enterprise commissioning high-impact, public-facing reconstructions of dinosaur species that were at the margins of our understanding of extinct life, leading to their obsolescence within a few short years (Witton and Michel, 2022).

With the potential pitfalls obvious, a question raised by such endeavours is: what drives the creation of expensive, highly-visible, widely-promoted dinosaur reconstructions from incomplete fossil remains? Science medialisation theory posits that science–media couplings benefit from seeking earlier publicity of results, no matter how provisional or controversial, for the increased authority and steering that such exposure brings to scientific discourse, as well as the interest and reputational boost it provides media agencies (e.g. Weingart, 1998). These goals probably extend, consciously or not, to the creation of iconic reconstructions of charismatic fossil animals and may override concerns – however legitimate – about their inherent restorability. Whether created by filmmakers, a scientific media company or a museum, the creation and promotion of a novel, iconic dinosaur reconstruction takes a certain amount of 'ownership' of that species and primes it for exploitation. Beyond *Spinosaurus,* history shows that there is great cultural and

commercial value in reconstructing unusual and impressive extinct species (Brinkman, 2010; Rieppel, 2019; Nieuwland, 2019) and our question, therefore, may not be about *why* companies and organisations invest so much in efforts to 'own' dinosaur species in this way, but why they do not do it more. (This phenomenon, of course, is not limited to dinosaurs: see Oliver Hochadel's discussion of 'Ida' in his chapter 'Palaeoanthropology and the mass media: an entangled history'.)

Critics of this approach and media-steered science in general (Weingart, 1998) might note that over-eager restorations of fossil taxa risk misleading the public about the status of a given fossil species, and confuse matters further with later efforts to correct the proliferation of erroneous, sometimes quickly outdated information. But *Spinosaurus* gives us grounds to wonder how valid such concerns are. Historically, such as when scientists first raised alarm over the longevity of superseded reconstructions in the nineteenth century (Niewland, 2019; Witton and Michel, 2022), slow media turnover could keep restorations of extinct animals persistent in popular media for decades after their obsolescence. But in researching this chapter, we found that the modern takes on *Spinosaurus* originating in Ibrahim and colleagues' 2014 and 2020 studies have assumed a prominent mantle among preceding interpretations, supressing, to some extent, even the mighty *Jurassic Park III Spinosaurus*. This could reflect a variety of factors, including the capability of a high-impact media release to thoroughly overshadow previous interpretations of a fossil species, something that does not, in our experience, occur through routine publications of new scientific papers or lower-key press events. In addition, we wonder if a shift towards rapid news turnover and media creation might now allow dinosaurs to transition to new interpretations with less baggage than in previous generations? These questions may be worth exploring in further detail elsewhere.

Perhaps, in addition, the tradition (and perhaps even expectation) of change and controversy around *Spinosaurus* has allowed it to have an especially evasive, dynamic public face. Whatever the general rule for dinosaurs, in the specific case of *Spinosaurus* it is perhaps this publicly visible *malleability* that is its greatest strength and weakness: the same property which makes it hard to restore incontrovertibly also makes it tantalising, eccentric, provocative and exciting, as it historically has for dinosaurs such as *Iguanodon* and *Megalosaurus*. We find that malleability matched at a formal level, as *Spinosaurus* shifts between the status of a curio, a superpredator, a monster, a cipher, a charismatic example of deep time's biodiversity. If the constant reinvention of *Spinosaurus* is now in danger of itself becoming a defining quality of the animal, it is perhaps

worth recalling that it is only an exaggerated instance of the uncertainty which plagues all dinosaur reconstruction. There is no extinct dinosaur for which our information is complete, and few indeed have not been passed to some extent through the prism of popular culture. At the same time, it must be acknowledged that definite and improving data on *Spinosaurus* does exist, and that the fantastical baggage it has accrued on its journey through human history works both in harmony and tension with our developing scientific knowledge.

Underlying this chapter has been a question about appeal: why wasn't *Spinosaurus* popular earlier, and why did it then become so? Any serious attempt at an answer necessarily involves an appreciation of national and international politics, the special status of dinosaurs in (some) media culture, and the history of art as well as palaeontological research. To say that artistic or scientific factors alone were responsible for *Spinosaurus*'s status at any given moment is clearly an oversimplification. But if we are to admit the perhaps uncomfortable power of a Hollywood franchise in bringing this animal to prominence, we must also confront the importance of solid bones, however few and however fractured. The indefinite, protean quality of *Spinosaurus* is powerfully alluring – but not more so than the fact of its reality, even when the most fundamental features of that reality remain subject to revision. It is not the science or the fantasy of *Spinosaurus* which sustains it, but both.

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