1 # Paleontology-themed comics and graphic novels, their potential for
2 scientific outreach, and the bilingual graphic novel *EUROPASAURUS –*
3 *Life on Jurassic Islands*

5 Oliver Wings[1, 2]
6 Jan Fischer[3]
7 Joschua Knüppe[4]
8 Henning Ahlers[5]
9 Sebastian Körnig[6]
10 Arila-Maria Perl[2]

13 [1]Natural History Museum Bamberg, Fleischstr. 2, 96047 Bamberg, Germany
14 Orcid ID: https://orcid.org/0000-0002-6482-6683
15 [2]Natural Sciences Collections, Martin Luther University Halle-Wittenberg, Domplatz 4, 06108
16 Halle (Saale), Germany
17 [3]Urweltmuseum GEOSKOP / Burg Lichtenberg (Pfalz), Burgstr. 19, 66871 Thallichtenberg,
18 Germany
19 Orcid ID: https://orcid.org/0000-0003-2379-7879
20 [4] Independent researcher, Idastraße 13, 49479 Ibbenbüren, Germany
21 [5] Independent researcher, Im Mühlentor 3, 31832 Springe, Germany
22 [6] Didactics of Biology, Martin Luther University Halle-Wittenberg, Weinbergweg 10, 06120
23 Halle (Saale), Germany.
24
25 Correspondence: Oliver Wings (wings@snsb.de)

28 Abstract:
29 The first part of this article gives an overview of influential comics and graphic novels on
30 paleontological themes from the last twelve decades. Through different forms of
31 representation and narration, both clichés and the latest findings from paleontological
32 research are presented in comics in an entertaining way for a broad audience. As a result,
33 comics are often chroniclers of 20th century scientific history and contemporary paleoart.
34 The second part of this article deals with the development of the bilingual graphic novel
35 *EUROPASAURUS - Life on Jurassic Islands*, which communicates knowledge from

36 universities as well as museums to the public. This non-verbal comic presents the results of

37 a paleontological research project on a Late Jurassic terrestrial biota from northern Germany

38 in both a scientifically accurate as well as an easily understandable way, based on the way

39 of life of various organisms and their habitats. Insights into the creative process, the

40 perception of the book by the public, and ideas on how to raise public awareness of such a

41 project are discussed.

43 1 Introduction

44 The communication of scientific research via contemporary and creative ways is becoming

45 more and more important for research institutions. Paleontological topics are often met with

46 special interest by the public, especially when it comes to vertebrate paleontology. From our

47 experience, maximum attention is paid to dinosaur research, which often reaches an

48 international distribution in the media, depending on the momentary situation on the global

49 news market. However, all press releases and subsequent press articles share one

50 disadvantage—their short-lived nature. After a maximum of several days, the reports are no

51 longer present in the media and will be quickly forgotten. Hence, this type of knowledge

52 transfer does not appear to be particularly sustainable.

53 Books on the other hand, are long-lasting and can accompany us our whole lifetime.

54 Unfortunately, text-heavy popular science books do not reach all groups in our society

55 equally (i.e., children from socially disadvantaged backgrounds) due to partially higher

56 barriers of accessibility. Easily accessible formats such as comics and graphic novels offer

57 opportunities to transmit science into possibly more neglected parts of our society.

58 This paper, consisting of two parts, addresses this issue with an example from the field of

59 paleontology. The first part provides an overview of the historical development of

60 paleontology-themed comics and graphic novels, the influence of paleoart in this genre, and

61 the potential of graphic novels in transmitting science into the public. The second part

62 focuses on the dinosaur-related graphic novel *EUROPASAURUS - Life on Jurassic Islands*

63 as an example. We explain our motivation for its creation, the production process, and our

64 strategy for advertising it, with the goal of encouraging other scientists to explain their

65 research results to the public in a similar fashion.

66

1.1 Paleontology within popular science books

Paleontological discoveries became known to a wider audience in the mid-19th century, due to public lectures, the first 'dinomania' following the creation of the Crystal Palace life-sized reconstructions of dinosaurs (Manucci and Romano, 2022), and the new spectacular dinosaur finds from the United States. Since then, manifold books, articles, and even collecting cards presenting the results and summaries of contemporary knowledge have been published. In the beginning, these publications were primarily addressed to an adult and educated readership (e.g., Flammarion, 1886; Knipe, 1905; Andrews, 1926; Bölsche, 1931; Knight, 1935; Augusta, 1942), but by the 1950's younger readers were also reached by a wide range of age-appropriate and lavishly illustrated books (e.g. Scheele, 1958; Watson, 1960; D'Ami, 1973; Norman, 1985). Nowadays, such children books dominate the market of non-professional paleontological publications, often resulting in a marginalization of dinosaur topics as 'kids' stuff' in the view of the general public (Liston, 2010). However, there were always outstanding paleontological popular science books for adult and mixed audiences as well (e.g., Augusta and Burian, 1956; Spinar, 1972; Stout, 1981; Cox et al., 1988; Norman, 1988; Czerkas and Czerkas, 1990; Holtz, 2007). All these books share a relatively text-intensive style, although many of them qualify as so-called 'coffee table' books with a variety of large-sized colorful illustrations. Unfortunately, the information contained on specific paleontological topics is often at least slightly outdated by the time of release, especially in children's books, a market where it is often not seen as necessary by publishers to be up-to-date. New ideas and paradigms in paleontological research take years to reach a non-academic audience and even decades to determine the perception of the general public on that topic (Ross et al., 2013). However, communication on the latest paleontological knowledge can be realized most quickly and effectively by a medium specifically aimed at a predominantly young audience (Liston, 2010)—the comic strip.

1.2 Influential paleoart

Paleoart is an art genre that depicts paleontological subjects realistically or artistically, reconstructing extinct biota and their habitats based on scientific data. Artists who strive to reconstruct prehistoric organisms and/or habitats as accurately as possible, often in close collaboration with paleontologists and other specialists (Germann, 1943), are so-called paleoartists (Hallett, 1987, Janzen, 2020). Although existing for about 200 years (Lescaze, 2017), paleoart still struggles for its reputation to be regarded as 'real' art compared to the 'classic' genres (Janzen, 2020). In recent decades, there have been many approaches to

appreciating, classifying, and assessing paleoart and paleoartists (e.g., Czerkas and Olsen, 1987, Lescaze, 2017, Hübner, 2020, Janzen, 2020, Manucci and Romano, 2022), even including instructions for making one's own attempts (Witton, 2018). Paleoart is a crucial link between paleontology and public awareness because paleoartists illustrate paleontological theories in their life restorations (Murray, 1997; Spindler, 2020).

Therefore, it is not surprising that contemporary paleoart has repeatedly served as a template for the depiction of prehistoric life in comics since the early 20th century. Without any paleontological research of their own, most comic authors and illustrators relied directly on preexisting visual ideas of the subject. Although often exaggerated in their presentation, the original artwork can often still be recognized in the animal contours, body postures, and sometimes even color patterns (Fig. 1). Many panel drawings were almost exact copies of their academic originals, which were recycled again and again. However, subsequent strips also independently aligned themselves with the prevailing scientific view and reconstruction (Murray, 1993, Liston, 2010). This transformation of contemporary paleoart and its underlying paleontological ideas into panels makes comics chroniclers of advances in paleontology. Many dinosaur comics thus accurately reflect contemporary paleoart and the paleontological paradigms of the time. In particular, the paleoart of the so-called 'Classic Era' from 1890 to the late 1960's (Witton, 2018) generated manifold inspiration and direct templates for comics. During this period a triumvirate of paleoartists, the preeminent authorities in the field, provided the 'graphical' fuel for memorable prehistoric worlds and impressive archaic antagonists. Their paleoart was responsible for establishing the standards of what dinosaurs should look like at the time, inspiring generations for how dinosaurs were to be portrayed. They were so widespread and well-known in cultural memory through books, comics and movies that even today many people are familiar with their work (Gould, 1993; Czerkas, 2006; Ross et al., 2013, Janzen, 2020), even though they may never have heard of their names.

The first of these most influential paleoartists was Charles Robert Knight (1874–1953). Knight was a classically trained artist who specialized in animal paintings. He is probably best known for his collaborative work on reconstructing extinct organisms with paleontologist Henry Fairfield Osborn at the American Museum of Natural History in New York (Paul, 1996). He also reconstructed many fossil taxa described by the rival paleontologists Othniel Charles Marsh and Edward Drinker Cope. Knight almost single-handedly established the field of accurate artistic reconstruction of prehistoric life in public perception (Gould, 2001; Bissette, 2003) and can be regarded as the first internationally renowned paleoartist (Witton, 2020). Part of his legacy is his rigorous approach to reconstructing extinct animals, providing

a guideline for subsequent generations (Knight, 1947). While his dinosaur reconstructions
are outdated today, many of his paintings and drawings of mammals still hold up to modern
standards. In two of the most famous and widely used templates of paleontological
reconstructions, Knight established *Brontosaurus* as a semiaquatic behemoth and
Tyrannosaurus and *Triceratops* as eternal enemies (Knight, 1935). In addition, his
surprisingly dynamic 'Leaping Laelaps' as well as numerous other murals and paintings
reproduced in books, periodicals, and journals (e.g. Knight, 1935, 1942, 1946; Czerkas and
Glut, 1982; Czerkas, 2006; Milner, 2012) provided a vast number of templates for prehistoric
lifeforms in comics. For example, the lost worlds with wonders and threats of the early
Tarzan and *Turok* series are unmissable testimonials to his work (Fig. 1a).

The second member of the triumvirate was Rudolph Zallinger (1919–1995). His contribution
to paleoart still echoes through paleontological history. While in his last year at the Yale
School of Fine Arts in 1942, he was offered to add "some kind of decoration" to a large wall
of the dinosaur hall at the Yale Peabody Museum. After pencil sketches and a preliminary
small-scale painting, or model, in egg tempera, Zallinger worked for three and a half years
on the 33.5 meter long mural *The Age of Reptiles*, a grand narrative of life from the
Devonian to the end of the Cretaceous. The mural was finished in 1947 (Volpe, 2007) but
did not become famous until a few years later, when Life magazine reprinted the
preproduction model as a foldable panorama (Life, 1953). With that, Zallinger's fresco-like
depictions of prehistoric life became the gold standard for portraying dinosaurs for years to
come. In 1949, Zallinger received the Pulitzer Prize for his mural. He later created more
paleoart for other publications (e.g., Watson, 1960; Zallinger, 1966), but his most influential
work remains *The Age of Reptiles*. In particular, Zallinger's iconic *Tyrannosaurus* was
frequently used in comic strips and serials until the 1960's (Fig. 1b). Entire stories, especially
in *Turok*, were graphically based on this single image of a dinosaur in side view.

The third cornerstone for the inspiration (and plagiarism, Sadecký, 1982b) of prehistoric
wildlife in countless comics was the Czech artist Zdeněk Burian (1905–1981), who may be
the most influential paleoartist of the mid and late 20th century (Reich et al., 2021). His work
shaped public perceptions of prehistoric life like no other (except Knight, depending on the
European or American perspective). Burian achieved this by his extreme productivity (with
some 1,300 images and preliminary sketches on prehistoric subjects; Rostislav Walica, pers.
comm.) and through his appealing, highly detailed images. He began his career as an
illustrator of adventure and science fiction novels (Sadecký, 1982a; Prokop, 2005). As such,
he was not only a master of various media, but also a skilled visual storyteller. Through his
work on novels about mammoth hunters (Štorch, 1937), he came into contact with the

171 paleontologist Josef Augusta and later with other scientists (Walica, 2003; Prokop, 2005).

172 These fruitful collaborations resulted in several lavishly illustrated large-format books on

173 evolution and the history of man (e.g., Augusta, 1942; Augusta and Burian, 1956, Spinar,

174 1972; Wolf, 1977). Despite the Iron Curtain, his works have been translated and exported

175 worldwide since the 1950's. Producing countless paleoart originals over several decades

176 (Müller and Walica, 2022), Burian can be considered the legitimate successor of Knight

177 (Witton, 2020). In comics, his first worldwide book success (*Prehistoric Animals* from 1956)

178 can be traced precisely to *Turok* #11 in 1958, where copies of his depictions of prehistoric

179 life started to complement and increasingly replace Knight and Zallinger's templates (Fig.

180 1c).

181

182

183 1.3 Comics and graphic novels about prehistoric life

184 Comics are a medium that expresses ideas with images. They often consist of sequences of

185 panels of images and are frequently combined with text or other visual information. Graphic

186 novels are books made up of comic content. They tell a longer and sometimes more

187 complex story and are distinct from 'comic books' that consist of comics, periodicals, and

188 trade paperbacks. Moreover, they represent a successful marketing concept for a form of

189 publication in which comics gain literary merit through book covers in order to be distributed

190 by major publishers in bookstores (Abel and Klein, 2016). A discussion of prehistoric topics

191 in cartoons is beyond the scope of this paper, although this theme and its sometimes even

192 bidirectional influence on paleontology (e.g., Gary Larson's "thagomizer"; Holtz, 2007) would

193 merit a review on its own.

194 Like most other comics, strips involving prehistoric creatures are aimed predominately at a

195 young target audience. The majority of previous and modern comics dealing with dinosaurs

196 and other prehistoric life serve as pure entertainment. They represent the absolute majority

197 of dinosaur comics with thousands of stories handling tales from science fiction, fantasy,

198 horror, mystery, western, or the superhero genre (Glut, 1980). Only a small but diverse niche

199 uses a different approach; not only providing enjoyable and thrilling stories, but also

200 contributing to the transfer of scientific knowledge and deepening the paleontological

201 background beyond the entertainment factor. This type of subtle education of the audience

202 may be achieved via individual panels with embedded information, via detailed elaborated

203 scientific content in a comic book style, or via a format in between.

204

205 Dinosaurs and their kin have always been a popular subject in comic strips. Starting as a
206 recurring inventory of excitement or terror in Sunday newspaper edition stories, extinct
207 animals later also got leading roles (sometimes as anthropomorphized characters) and even
208 sequel stories (Glut, 1980; Murray, 1993; Bissette, 2003). They were used in several
209 contexts, from entertainment to education, with a variety of formats between. The strips
210 grouped thematically below are a limited selection without any claim to completeness.
211

212 Adventure stories
213 The first and foremost use of prehistoric life in comics was—and still is—for the purpose of
214 pure entertainment without any interest in paleontological education. Prehistoric animals are
215 shown just as forces of nature. They are necessary to advance the story as villains (or
216 heroes) or a MacGuffin (an object that is necessary to the plot, but insignificant in itself), and
217 are merely used to create tension and action (Glut, 1980). The animals are usually depicted
218 as dangerous, vicious, stupid, carnivorous, and often pose supernaturally large threats for
219 the human protagonists. Commonly, the prehistoric lifeforms do not survive the encounter
220 with humans. These strips are essentially not dinosaur comics but comics with dinosaurs
221 (Bissette, 2003). Three recurring specific settings are widely used (Galle, 1993) to explain
222 the presence of the prehistoric creatures: 1) lost-world areas, a realm where they survived
223 until today; 2) other planets, strange worlds with primordial plants and animals; and 3) time
224 travel, the journey into their time or their retrieval into modern times.
225 The earliest comic reference to dinosaurs is *Prehistoric Peeps* from 1893 (Merkl, 2015), in
226 which prehistoric humans and dinosaurs satirically reflected and caricatured the present in
227 anachronistic situations. A subsequent example of more prehistoric encounters is the classic
228 Saturday newspaper comic strip *Dream of a Rarebit Fiend* by Windsor McCay, where
229 dinosaurs repeatedly appeared between 1905 and 1913, and were remarkably accurately
230 drawn by the standards of the time (Merkl, 2015). One of these comic pages (Fig. 2a)
231 already foreshadowed a topic McCay later reworked in his well-known animated dinosaur
232 film *Gertie the Dinosaur* in 1914 (Nathan and Crafton, 2013). Another classic newspaper
233 strip, *Madge, the Magician's Daughter*, also used a diverse dinosaur menagerie already by
234 1907 (Fig. 2b) to show a museum trip from a surprising new side (Wilson, 2010). A more
235 serious encounter was depicted in a multiple part Sunday edition of Edgar Rice Burrough's
236 *Tarzan* by Harold Foster from 1932, where the protagonist met a carnivorous (!) sauropod,
237 countless pterosaurs, and finally survived the attack of a giant and impressively colorful
238 *Tyrannosaurus rex* (Fig. 2c; Carlin and Foster, 2013). It took another five years before the
239 next comic dinosaur appeared. In 1937, *Prince Valiant* faced a sauropod-like swamp-
240 monster, which he defeated in the end. Tarzan's second encounter with a *T. rex* happened

241 in 1945 in Burne Hogarth's strip, where Tarzan managed to impale the obtrusive carnivore
242 (Hogarth, 2016). With #4 of the *Tarzan Comic* in 1948, dinosaurs finally became a regular
243 part of recurring Lost World stories for about 20 years, shaping many subsequent strips in
244 their representational form and color scheme (Fig. 2d; DuBois and Thompson, 2017). Other
245 comic serials started to use the potential of prehistoric threats and primordial adventures too,
246 and prehistoric topics have flourished in countless issues ever since (Murray, 1993; Glut and
247 Brett-Surman, 1997; Bissette, 2003). To date, nearly every superhero (team) in any
248 franchise has had its own encounter with members of the Dinosauria or other prehistoric
249 lifeforms (Glut, 1980). Starting in 1960 in *Star-Spangled War Stories* #90 by DC, US soldiers
250 were repeatedly confronted with over-sized Mesozoic creatures on countless Pacific islands
251 during World War II (Fig. 3a). It was not until 1968 that this *War That Time Forgot* ended
252 after 45 explosive clashes in #137. In the German Piccolo comics from the 1950's such as
253 *Akim, Sohn des Dschungels* [*Akim, Son of the Jungle*], *Sigurd, der ritterliche Held* [*Sigurd,*
254 *the Knightly Hero*] or *Raka, der Held des Jahres 2000* [*Raka, Hero of the Year 2000*], the
255 protagonists experienced adventures with most stereotypical dinosaurs on a regular basis
256 (ComicSelection, 2019). Even in the cataclysmic future world of *Xenozoic Tales* from 1987,
257 also reprinted under the title *Cadillacs and Dinosaurs*, a variety of marvellous illustrated
258 prehistoric animals, especially dinosaurs, complicated the postapocalyptic life of the two
259 main characters for 14 issues (Fig. 3b; Schultz, 2013).
260 However, there are also peaceful encounters with the prehistoric menagerie in thematically
261 quieter and more child-friendly comic series. In 1957, Donald Duck and his nephews
262 unintentionally experienced a 'Forbidden Valley' lost world adventure in *Walt Disney's*
263 *Donald Duck* #54 (Fig. 3c). In 1974, German *Fix und Fax (*#193–199) also visited a colorful
264 prehistoric setting (inspired by drawings from Bölsche, 1931) without causing collateral
265 damage among the inhabitants (Fig. 3d; Kieser, 2018). A similar story was told in a short
266 episode for the protagonist trio Abrafaxe in *Mosaik* #216–217, where they accidentally time
267 travelled to the Cretaceous (Fig. 4a; Schleiter, 2011). In series such as *The Adventures of*
268 *Tintin* (Hergé, 1947) and even *Asterix* (Fig. 4b; Ferri and Conrad, 2021), dinosaurs appeared
269 as MacGuffins instead of antagonists. In *Calvin and Hobbes*, prehistoric worlds are regular
270 retreats of fantasy from the dreariness of everyday life (Watterson, 2012).
271
272 Adventure stories supported by educational information
273 Besides pure adventure stories with prehistoric inventories, more educational approaches
274 have been realized too. The Dell serial *Turok, Son of Stone* also chose a lost world setting.
275 Starting in 1954, it became the longest running dinosaur serial with altogether 131 issues
276 until 1982. Two native Americans, Turok and his young companion Andar, discover a lost
277 valley full of largely-varied, preferably dangerous ancient lifeforms. While all stories dealt

278 with their unsuccessful attempts to leave this inhospitable place, they met (and killed)

279 countless prehistoric creatures (Fig. 5a). In contrast to *Tarzan*, where the dinosaurs were

280 only a means for entertainment, the *Turok* authors provided additional information about

281 prehistoric life to the reader. Supplementary pages were included in every issue, detached

282 from the *Turok* universe. As of 1956, text pages about specific animals with illustrations as

283 headers were included—strongly reminiscent of chocolate trading cards from the first half of

284 the 20th century (Bölsche, 1916). By 1957, the additional separate short strip *Young Earth*

285 was established to alternate with the main story in every issue (Fig. 5b), focusing solely on

286 the prehistoric animals and explaining aspects like animal behavior or evolutionary patterns.

287 While most of these stories mixed Paleozoic and Mesozoic taxa indiscriminately, they can be

288 seen as the vanguard of the true dinosaur comics of the future. Similar approaches of

289 additional brief scientific background information were used in the Dell Movie Classics, such

290 as #845 (*The Land Unknown* 1957), #1120 (*Dinosaurus!* 1960), and #1145 (*The Lost World*

291 1960), to supplement the stories in the related films. Another example is the space storyline

292 of the German Digedags in *Mosaik* between 1961 and 1962 (Hegen, 2004, 2006). For ten

293 issues, starting with #51, the protagonists investigated several planets with different stages

294 of earth's evolution (even in the correct evolutionary order) (Fig. 5c), while the back cover in

295 each issue summarized scientific facts. The same approach, although from another

296 perspective, was used recently in *Paleocene* by Mike Keesey. Here, we see the world

297 through the eyes of anthropomorphized lemur-like primates just a decade after the asteroid

298 event that killed the dinosaurs, leaving behind a devastated world at the dawn of a new era.

299 While the primates try to survive against avian dinosaurs, the non-avian dinosaurs still exist

300 as dragons in fairy tales of the elders (Fig. 5d). Concise scientific facts introduce every issue

301 and provide framework and context for the events.

302

303 Adventure stories supported by sophisticated educational information

304 In tradition and as an extension of the *Young Earth*'s narrative style, longer stories were

305 produced with a scientifically more robust background and naturalistic depictions of the

306 animals and environments. The focus in these modern comics was on the needs,

307 experiences, but also failures of the dinosaur protagonists. *Paleo* is an anthology of a dozen

308 different dinosaur stories from the Late Cretaceous in detailed monochrome panels,

309 highlighting also other animals such as marine reptiles and pterosaurs (Fig. 6a; Lawson,

310 2016). In contrast, *Tyrannosaurus rex* focused on a feathered tyrannosaurid individual,

311 Cobald, and its daily struggle to survive and to find a mate in the latest Cretaceous (Fig. 6b;

312 Rechlin, 2016). Subsequent volumes have extended this concept to other dinosaurs, as well

313 as the evolution of sharks, whales, and Ice Age mammals (e.g., Rechlin, 2018, 2019).

314

Self-narrative storyboards

Another approach is text-reduced visual storytelling, similar to a sophisticated storyboard. This comic format is used in *Age of Reptiles* by Dark Horse Comics (Delgado, 2011, 2015), which depicts the fate of several dinosaurs in four stories: *Tribal Warfare* from 1993 featured a conflict between a *Tyrannosaurus* family and a pack of *Deinonychus*, *The Hunt* from 1996 followed a vendetta involving an *Allosaurus* and a group of chameleon-like *Ceratosaurus*, *The Journey* from 2009 showed the annual migration of various Cretaceous dinosaurs herds to new feeding grounds, and *Ancient Egyptians* from 2015 depicted a brief period in the life of a *Spinosaurus*. While the first two stories partially anthropomorphized their non-human protagonists in their overly violent action and motivation, subsequent stories were told closer to the tradition of animal documentaries, attempting to avoid uncharacteristic animal behavior and interactions. The paleontological background is not explained further. Instead, the reader is challenged to extract all information from the colorful dynamic drawings (Fig. 6c). A similar approach was used in *Cretaceous* (Galusha, 2019) which tells the story of a *Tyrannosaurus* family struggling with a group of marauding *Albertosaurus* and obtrusive dromaeosaurs of all sizes. The pace of the story is further driven by the creative and dynamic use of panels (Fig. 6d). Another text-reduced *Tyrannosaurus* adventure is *Love: The Dinosaur*, where the vicious lead character interacts with more comic relief dinosaurs to finally witness the inevitable asteroid impact (Brremaud and Bertolucci, 2017).

Comic science books

Paleontological information has also been conveyed through a direct implementation of popular science book content in comic style. For example, an adventurous story with (intrusive) human protagonists can be abandoned in favor of imparting knowledge transfer through panels with text boxes. Classics Illustrated used this concept twice to present a volume on paleontological knowledge of its time: in Classics Illustrated issue #19 *The Illustrated Story of Prehistoric Animals* from 1959, and in its successor, Classics Illustrated Special #167A *Prehistoric World* from 1962 (Fig. 7a). Several chapters present the history of paleontology, the evolution of life, and the history of humankind in comic book form. In the comic adaptation of the 1978 French animated series *Once Upon a Time… Man*, the history of the earth before the appearance of humans was summarized in panels on several pages in the first volume (Gaudin et al., 2021), together with the series actors as well as the characteristic time clock (Fig. 7b). More recently, a more reflective account was provided in *Alpha …Directions* by Jens Harder, detailing the evolution of life up to the appearance of humans. *Alpha* used classic iconic depictions from books, articles, movies, TV shows, and also other comics to summarize concepts and mechanisms for evolution as well as the

351   development of life according to current understanding in collages of science and pop

352   culture. Short accompanying sentences articulate the main idea or message of each collage.

353   (Fig. 7c; Harder 2010). Another ambitious science comic, *Evolution: The Story of Life on*

354   *Earth* (Hosler et al., 2011), provides insights into evolutionary processes on Earth, including

355   paleontological topics, through black and white panels. The content covers highly complex

356   processes in an understandable way through entertaining one-liners of extant and fossil

357   organisms, presented and explained by an alien scientist in his holographic museum. In

358   *Science Comics: Dinosaurs* (Reed and Flood, 2016), the narrative structure follows the

359   history of scientific discoveries. The scientists portrayed, and sometimes even the dinosaurs,

360   were given speech bubbles to convey relevant information. In the *Earth Before Us* trilogy by

361   Abby Howard (Howard, 2017, 2018, 2019), we follow a scientist and a young girl through the

362   geological eras. Readers get information about evolution, experience the variety and beauty

363   of these lost worlds, and learn about the pronunciation of Latin names (Fig. 7d). Even a

364   glossary is provided. While most information is conveyed by the protagonists in speech

365   bubbles, some pages depicting animals in a particular ecosystem resemble puzzle pictures.

366

Genre potpourri

368   The previously mentioned comic styles can also be mixed (i.e., a documentary-style

369   narrative storyline with supporting text boxes supplemented by textbook-style background

370   information). Marvel's *Dinosaurs, a Celebration*, a four-issue series on stand-alone dinosaur

371   comic narratives by various artists and authors was first published in 1992. Each issue

372   contains four short, visually varied stories about different taxa, accompanied by blocks of

373   descriptive text, as well as textbook-style pages on different paleobiological topics

374   alternating with the stories. *Stephen R. Bissette's Tyrant* from 1994 tells the story of a

375   breeding *Tyrannosaurus* and an egg-hunting *Chirostenotes* in four issues (Bissette, 1994),

376   with ultimate consequences for one of them (Fig. 8a). The monochrome story focuses on

377   these protagonists, but also highlights other creatures such as insects, spiders or turtles of

378   the Cretaceous ecosystem. Finally, an entire volume is devoted to the development of the

379   embryo in the egg, which is probably unique in its complexity in the comic field. Scientific

380   information about the animals and their behavior is provided in an appendix to each issue.

381   The book series *Dinosaurs* (Bacchin and Signore, 2008) devotes each of the six volumes to

382   a particular Mesozoic ecosystem centered on distinct dinosaurs: *Plateosaurus*,

383   *Archaeopteryx*, *Allosaurus*, *Scipionyx*, *Argentinosaurus*, and the inevitable *Tyrannosaurus*.

384   In each volume, about 40 pages of graphic novel (Fig. 8b) are followed by 20 pages of

385   extensive textbook with detailed background information on the depicted taxa, their

386   phylogenetic position, size comparisons, as well as general information on dinosaur

387   evolution and paleontology. Finally, there is *Mimo on the dinosaur trail* (Mazan et al., 2016)

388 about the results of the dinosaur excavation in Angeac-Charente, France. The
389 ornithomimosaur Mimo and his carcharodontosaur friend Hector face an unknown danger
390 together. The Cretaceous ecosystem is introduced as this story develops. After the comic
391 section with text blocks and speech bubbles, making up almost half of the volume, there is
392 an illustrated outline of the fauna followed by an account in sketchbook form of the real
393 excavation with explanations of the work steps and an introduction of the human
394 participants.
395

1.4 Graphic novels as a tool for teaching science

397 Today, paleoart is the most commonly used medium to communicate paleontological topics
398 to the public. It can not only provide ideas about the ecosystems of the past, but it can also
399 help to increase interest in them (Berta, 2021). Therefore, it is obvious to use this medium of
400 science communication in the form of a graphic novel. Research institutions address diverse
401 target groups and educational levels in order to interest a broad audience in their research
402 activities and findings. In this way, they break down barriers—including invisible ones such
403 as language barriers—and can offer scientific content in a way that engenders equal
404 opportunities and self-determined participation (Leidner, 2007; Metzger, 2016). Through this
405 form of inclusion, very individual levels of receptivity, needs, and knowledge levels are
406 equally addressed in a format-friendly manner. Interested readers can thus approach
407 specialized topics from different perspectives. This enables readers to independently
408 experience content and gain knowledge. Simultaneously, it helps the pursuit for greater
409 inclusion in our society (Abel and Klein, 2016; Wong et al., 2016; Metzger, 2016).
410
411
412
413 Our sensory nervous system is stimulated by a variety of sensory data. In that process, our
414 senses automatically and constantly carry out selection processes of incoming information
415 (Kahlert, 2000). Graphic novels are especially suited to focus our attention on specific
416 senses. Images, in particular, often show something unexpected and can either complement
417 or challenge prior knowledge, which in turn can trigger emotions and increase interest.
418 Books and images can thus be used creatively as didactic material in the classroom. For
419 example, a graphic novel with a scientific background may serve as a valuable
420 complementary tool in the classroom, even when not directly related to the curriculum
421 (Tatalovic, 2009).
422

423   Museum and collection knowledge transfer necessitates creating access to knowledge
424   through a variety of aesthetic forms of presentation. These forms range from dioramas and
425   room-filling illustrations to graphic literature such as graphic novels with page-filling images
426   with little to no text. The latter can increase interest in technical topics as well as improve
427   reading comprehension (Abel and Klein, 2016; Wong et al., 2016). Moreover, a graphic
428   novel finds its readership among adults and yet does not exclude children, teens, and
429   families because very little text comprehension is required (Abel and Klein, 2016; Wong et
430   al., 2016). Haptic experiences with paper are often described by children as authentic and
431   real, and therefore preferred for learning, as compared to viewing digital books (Sax, 2016).
432   The latter ultimately remains dependent on the technology used and its availability.
433
434   Studies show that comics are suitable for teaching natural sciences to children (e.g.,
435   Farinella, 2018; Spiegel et al., 2013; and references therein). Even the often difficult-to-reach
436   target group of young adults (often referred to as the 'virtual' generation in the age of
437   smartphones and digital media) can be addressed by means of graphic novels (Yang, 2008).
438   Young adults are stimulated in their imagination by the illustrations and receive the content
439   through independent exploration (Tatalovic, 2009, Short et al, 2009). The general suitability
440   for a diverse community of interest within a wide variety of backgrounds lies in the anchoring
441   of comics in everyday life (Tatalovic, 2009). This broad audience wants to be met by
442   adequate forms of communication and be encouraged to think about scientific content
443   (Tatalovic, 2009).
444
445   Barrier-free access can be achieved by offering at least two sensory styles ('two-senses
446   principle'; Metzger, 2016): an illustrated book with a reduced amount of text (for example an
447   exhibition catalog) can be picked up repeatedly and continues to function as a mediator
448   while creating memories. The combination of images and reduced text also supports student
449   learning (Wong et al., 2016). Science communication can use this 'multimedia approach' to
450   communicate topics with a lasting effect, especially since much more information can be
451   conveyed in a picture than in a length-limited text. Graphic novels can increase interest in a
452   topic through this interplay of image and text (Wong et al., 2016).
453
454   However, illustrations can still leave room for misinterpretation (Wong et al., 2016) and are
455   therefore often only a complementary element to the communication of knowledge. This
456   element, created through the collaboration of artists and scientists, gains credibility and
457   authenticity in interaction with original objects, dioramas, and reconstructions (Klein, 2004;
458   Berta, 2021). Whereas dioramas or individual drawings tend to 'freeze' a particular moment
459   in time (Abel and Klein, 2016), a continuing story in a graphic novel allows for a change in

460 perspective and better represents the multi-faceted nature of extinct organisms and
461 ecosystems.

462

2 The EUROPASAURUS graphic novel: defining a new niche of scientific credibility in graphic novels

2.1 Motivation

466 As laid out in section 1.4, graphic novels possess several benefits for science
467 communication. In other natural sciences, the use of such educational graphic novels is
468 more widespread. Environmental sciences, for example, lead the way. They do not only
469 cover the climate crisis (e.g., Squarzoni and Whittington-Evans, 2014) but also general
470 environmental work (e.g., Bertagna and Goldsmith, 2014), waste problems such as the
471 Great Pacific Garbage Patch (Allison, 2012; Harris and Morazzo, 2013), severe changes in
472 the biosphere (Kurlansky and Stockton, 2014), or suggestions of personal changes to
473 reduce the carbon footprint (Dávila, 2011).
474 While guide books for the creation of graphic novels in general do exist (e.g., McCloud,
475 1993; McCloud, 2006), together with countless online blog posts and videos, we did not use
476 any of them actively in the creation of our book. Strangely, however, special literature
477 regarding the creation of educational graphic novels does not seem to exist. To remedy this
478 situation, we would like to share what we learned in creating our graphic novel and from a
479 survey among the readers of this book.
480 The origin of our graphic novel lies in the active science communication that was carried out
481 continuously during a paleontological research project about the dinosaur *Europasaurus*
482 (see section 2.2). This science communication involved not only regular press releases
483 about new discoveries and technical articles, but also talks as well as guided tours at the
484 actual excavation site. The idea for a popular science book, or more precisely, for a graphic
485 novel was born after several years of exchange with the interested public. Our plan was to
486 create a colorful work that would be both exciting and scientifically plausible. Hence, this
487 approach falls into the "Genre potpourri" in dinosaur comics from section 1.3. Most similar is
488 the approach in *Mimo on the dinosaur trail* (Mazan et al., 2016), which has a similar purpose
489 and presents the excavation results from Angeac-Charente in western France (Allain et al.,
490 2022) with its diverse flora and fauna in an age-appropriate way. There are significant
491 differences in content and style, but the overall aim of immersive presentation of excavation
492 results is remarkably identical. At the time of the EUROPASAURUS graphic novel's idea

development, however, *Mimo* was not known and thus served neither as a template nor inspiration. It shows, however, that different people can independently develop similar ideas for transferring knowledge.

Out of the practically endless ways to tell a story in a graphic novel (for some suggestions see section 1.3) we decided on several basic parameters: 1) a documentary approach without anthropomorphized main characters, 2) a calm narrative style, and 3) the integration of scientific facts and references to actual fossil finds. Because only dinosaur books up to elementary school age were available on the German book market, our goal was to reach an older audience while also attempting to close the gap towards the specialized literature. However, the target group of our book was basically all people interested in the geological past, visual media, and/or illustrated works. Special focus was given to children from about ten years, teenagers, and young adults, who often seem to have outgrown their 'dinosaur enthusiasm' from early childhood. These young readers are able to experience the life of dinosaurs visually and enjoy easily accessible media content such as graphic novels and digital motion comics. Readers are required to have little or no prior knowledge of the subject. The content is easily understood through the narrative in pictures and aims to spark interest in more information. Even without reading the text, the book's design allows following the story. The focus of a graphic novel is of course on the graphic narrative part, but at the same time, background information in the appended factual section includes state of the art research results in easy language. From the beginning, the book was planned to be bilingual German/English in order to expand the readership beyond a German-speaking audience. With these ideas in mind, we developed several research questions and addressed them in an online survey (see section 2.3).

2.2 Scientific background

The *Europasaurus* Project researches one of the most important Mesozoic sites for fossil vertebrates in Europe—the Langenberg Quarry at the northern rim of the Harz Mountains near Goslar in Lower Saxony, Germany. The peculiarity of this site is the inclusion of fossils of terrestrial vertebrates such as lizards (Richter et al., 2013), crocodylomorphs (Schwarz et al., 2017), pterosaurs (Fastnacht, 2005), the dwarf sauropod dinosaur *Europasaurus holgeri* Sander et al., 2006 (Carballido and Sander, 2014; Marpmann et al., 2015; Carballido et al. 2020), and theropod dinosaurs (Lallensack et al., 2015; Gerke and Wings, 2016; Evers and Wings, 2020), which are limited to a few layers next to commonly occurring marine fossils (Wings and Sander, 2012). The vertebrate remains were transported into the shallow marine depositional environment during the Kimmeridgian (Late Jurassic, about 154 million years

ago; Zuo et al., 2018). At that time, Europe was still a tropical archipelago. The terrestrial fossils came from a nearby island and, in addition to land plants, include predominantly the remains of dinosaurs but also many other vertebrate groups. Bones and teeth of the small sauropod dinosaur *Europasaurus* are particularly common. With a maximum height of three meters and a length of eight meters, this macronarian sauropod was much smaller than its closest relatives, who rank among the largest land animals of all time. Food sources of *Europasaurus* were probably limited on the island, which may have led to island dwarfism over time—a recurring pattern throughout evolution (Sander et al., 2006). The discovery of the first Jurassic mammals in Germany (Martin et al., 2016, 2019, 2021a, 2021b) and a number of other new taxa added to the success story of this research project. Due to the large number of unusual and well-preserved fossil finds, which due to their often fragmentary nature reveal little to non-specialists, a visual reconstruction of the living world of that time was tantalizing. A grant for innovative high-profile scientific outreach allowed the realization of a special project: the graphic novel *EUROPASAURUS - Life on Jurassic Islands* (Wings and Knüppe, 2020), presenting the results of many years of research on fossil organisms from Langenberg and their Late Jurassic ecosystem in an easily accessible form.

2.3 Methods & Ethics

Because several of our ideas and reasoning in creating this graphic novel were rather guesswork than solid facts, we decided to ask our audience some questions via an online survey.

The background to the survey was centered around the following questions:
1. Are graphic novels as analogue media generally of interest and is this interest age-dependent?
2. In the opinion of the interviewees, are graphic novels suitable for conveying (natural) scientific content?
3. In the opinion of the interviewees, are bilingual graphic novels also suitable for teaching a foreign language?

Almost two years after the publication date of the book, we started to address these questions in an online questionnaire. Fortunately, it was possible via Social Media to reach out to a large number of readers and an online survey was designed using Google Forms. The aim of the anonymous online survey was to record the general impressions of the graphic novel in terms of its design and structure on the recipients. Furthermore, the

561 suitability of the book for conveying scientific content and foreign language skills was

562 evaluated. The survey was carried out as a questionnaire with mostly 5-point Likert scales.

563 The collected data was processed using Microsoft Excel and evaluated with the statistical

564 software pspp with regard to Pearson correlation (r) of the scales and significance (p), with

565 $0.5 < |r| \leq 0.8$ for a clear linear connection and $0.8 < |r| \leq 1.0$ for high to perfect linear

566 connection of the scales. A p-value < 0.05 is considered significant. In addition, the

567 participants had the opportunity to verbally formulate comments regarding three other

568 aspects. The answers to these open questions were addressed in a thematic analysis.

569 Furthermore, we started a preliminary thematic analysis of the reviews of the book on the

570 Amazon website.

571 All information was treated as strictly confidential in accordance with the EU General Data

572 Protection Regulation (GDPR) and according to the guidelines of the Department of

573 Didactics of Biology at the Martin Luther University of Halle-Wittenberg. All research results

574 and survey information were only used in an anonymous form, the identification of individual

575 participants in the questionnaire is impossible.

576

2.4 Survey results

578 A total of 152 persons participated in the survey. This number is well above the

579 recommended minimum number of 120 samples for statistical analyses and thus allows 90%

580 confidence intervals for the endpoints of the normal range (Reed et al., 1971). The majority

581 (69.7%) of the participants were male. Of all participants in the survey, more than half

582 (52.3%) consider themselves to have very good knowledge of paleontological topics,

583 another quarter of the participants (25.2%) estimated their paleontological knowledge still as

584 good.

585 Surprisingly, the age structure of the participants was quite mixed (Fig. 9a), with the group of

586 16-25-year-old making up over a third (37.5%) and those over 25 making up just over half

587 (54.6%). Most readers picked up the book several times (Fig. 9b). The frequency of

588 engagement with the book was not dependent on age (p=0.577). The basic interest in

589 graphic novels or comics (Fig. 9c) is also not significantly (p= 0.325) age-dependent among

590 the test persons. Within this sample, overall rating (r=0.037; p=0.652), extent of prior

591 knowledge (r=-0.105; p=0.202), and interest (r=-0.125; p=0.126) were found to be equally

592 independent of age.

593 The estimated increase in knowledge through the graphic novel (Fig. 9d) of the remaining

594 22.5% of the respondents with no or little prior knowledge, however, differed only marginally

595 from that of the entire sample (3.45 vs. 3.46 in the mean), so that an increase in knowledge

596   can be assumed for all respondents to about the same extent, which then, however,

597   probably refers to different, previously unknown areas. Overall, 16.4% of the respondents

598   found the graphic novel interesting and 80.9% even very interesting. An almost identical

599   picture emerged from the evaluation of the book in the form of awarding stars (* - worst

600   evaluation, ***** - best evaluation), with 82.5% awarding five stars and 15.8% awarding four

601   stars.

602   Regarding the suitability of graphic novels for science communication, over 96% of the

603   participants found it to be a useful (15.8%) or very useful (80.9%) tool for knowledge transfer

604   (Fig. 9e). This underlines the applicability of graphic novels for knowledge transfer, as

605   significantly fewer participants indicated a great (28.3%) or very great (28.9%) interest in

606   these media when asked for their general interest in graphic novels or comics (Fig. 9c). An

607   extremely high significance was shown with the participants, who indicated a basically large

608   interest in comics and graphic novels, these evaluated this book as very interesting

609   ($p=0.000$). The extent of the factual part was considered to be enjoyable by most readers

610   (Fig. 9f).

611   A comprehensible preference of the native language, both in the graphic and in the factual

612   part of the book, could be recognized. However, about a third of the participants (29.6%)

613   read also all texts of the graphic part in the other language, with the factual part, it was still

614   about a quarter of all participants (23.7%). The bilingualism of the book as a whole was

615   evaluated by the predominant number of the survey participants as a good (20.4%) or very

616   good idea (64.5%) (Fig. 9g). Furthermore, about two thirds see the bilingualism as rather

617   positive for the learning of a foreign language (36.2% beneficial and 32.9% very beneficial)

618   (Fig. 9h). There was a strong correlation between engagement with graphic and factual

619   sections in the foreign language ($r=0.89$).

620   With regard to the assessment of the appropriateness of the pricing, at least the test persons

621   who gave high ratings felt that the book was appropriately priced ($p=0.000$) and would buy it

622   again or recommend it to others ($p=0.000$). The situation was different when respondents

623   were asked if they would look at the book with children. Even though 52.6% of the

624   respondents would definitely look at the book with children and 30.3% stated that this was

625   still likely, there was no dependence on the general evaluation ($p=0.716$, $r=0.030$).

626   In addition to the survey, the participants had the opportunity to verbally comment on three

627   different aspects of their engagement with the graphic novel. The first question related to

628   scenes or sections in the book that were particularly memorable. 108 participants

629   commented on this. From the responses, the following categories of design or plot were

630   highlighted based on the frequency of mentions (more than 10 mentions). Frequent positive

631   statements about the design referred to the realism or detail of the drawings (22 mentions;

632   20.4%), while 21 mentions (19.4%) emphasized the artistic design in the form of different

633 perspectives and views. The depiction of the biodiversity of living creatures was also felt to

634 be particularly impressive (16 mentions; 14.8%). In addition, many different individual

635 depictions were mentioned, the most common of which was the depiction of the

636 thunderstorm (pages 72-75, 20 mentions; 18.5%).

637 The second question was aimed directly at what single aspect the participants liked best.

638 Among the 120 responses, more than ten mentions each fell into four main categories: The

639 quality of artistic representations was mentioned by 59 (49.2%) participants, 22 (18.3%)

640 participants particularly highlighted the representation of biodiversity, 21 (17.5%) participants

641 liked the factual part the most, and 12 (10%) people preferred the story.

642 97 participants also answered the last question, which asked for suggestions for

643 improvement. In this regard, 42 people (43.3%) stated that they could not make any

644 suggestions for further improvement in terms of complete satisfaction with the graphic novel.

645 A more extensive factual section was recommended by 10 persons (10.3%), while two

646 persons (2.1%) felt it was too long. Another five people (5.1%) suggested even more panels.

647 On the Amazon webpage, the EUROPASAURUS graphic novel has as of now (November

648 11th, 2022) 44 ratings with an average score of 4.6 out of 5 stars. Fourteen customers left

649 written reviews, of which nine originated in Germany, two are from Great Britain, two from

650 the USA and one from Japan. Among the twelve non-professional reviews, four positively

651 emphasized the bilingualism, eight praised the content approach (scientific background,

652 story, topic), and four commented positively on the factual part (stirring interest, appreciation

653 of the scientific elaboration). Two reviewers appreciated the scientifically correct

654 representation of the actual processes, especially the (bloody) acquisition of food by

655 predators via hunting prey whereas also two people doubted the correct representations

656 (e.g.: of the animals). Regarding the possible target group, four suggest everyone who likes

657 dinosaurs (including adults) while also four reviewers see it as suitable preferably for

658 children at least six/seven years old. One person was inspired to look into the fossil site and

659 planned to visit it. Two reviews recommended the book to others or did buy it again.

660

661 2.5 Discussion of survey results

662 Based on the results of this survey, the research questions formulated at the outset can be

663 answered as follows: graphic novels, and this book in particular, meet with a very high level

664 of interest due to both the quality of the design and the structuring of the content, and this is

665 independent of both the age and prior knowledge of the readers. In the opinion of the

666 interviewees, graphic novels are quite suitable for conveying scientific content and, at least

667 in this case, lead to a clear increase in knowledge among both pre-educated persons and
668 laypersons. Moreover, bilingualism is seen as a good means of teaching a foreign language.
669 However, it should be noted that the selection of test persons does not represent a random
670 cross-section of recipients, but that the participants decided to participate voluntarily and
671 thus possibly have a generally higher interest in graphic novels and/or paleontology.
672

673 2.6 Storytelling with facts and fiction: The balance between
674 entertainment and scientific accuracy

675 For an especially vivid impression of this Jurassic ecosystem, the situations and behaviors
676 shown in the images were chosen to be as diverse and visually creative as possible. In
677 addition to fossil finds, analogies and comparisons with living animals and comparable
678 habitats, as well as examples from the history of art and paleoart, served as inspiration. For
679 example, the painting *Der Abend* by Caspar David Friedrich served as an initial inspiration
680 for the composition of a forest scene at dawn, while the colors in this picture were mostly
681 inspired by classic landscape paintings of Edwin Church (Fig. 10). A storm scene (Fig. 11) is
682 a loose homage to the sea paintings by William Turner and Winslow Homer, while clouds on
683 the following page can partially be traced back to influences by Albert Bierstadt (Fig. 12).
684 Overall, the work of the Hudson River School, a group of landscape painters that included
685 Church and Bierstadt (Avery et al., 1987), left an impression on many pages of the graphic
686 novel. On the paleoart side, the work of Douglas Henderson was an important inspiration,
687 especially his handling of light and shadows, structure of the images but also, for example,
688 his use of dead wood. Additionally, major paleoart influences came from John Gurche's,
689 John Conway's, Mark Hallett's, and Todd Marshall's works.
690

691 We hoped that the graphic novel (although inevitably rendered outdated sooner or later by
692 scientific advances) would provide a visually and intellectually appealing medium that will
693 continue to excite future generations about the fossil flora and fauna of the Langenberg
694 Quarry and paleontology in general.
695 The plot of the story revolves around the experiences of a juvenile individual of
696 *Europasaurus*. Interwoven with subplots of various protagonists such as a series of
697 predatory dinosaurs, marine crocodiles, turtles, pterosaurs, small mammals, lizards, and
698 dwarf land-dwelling crocodyliforms, the story thus provides an overview of the entire
699 ecosystem. Major events such as a storm, a lightning strike, and a fire serve as overarching
700 plot highlights.

701   Due to the demand for scientific accuracy in the presentation (in contrast to a classic comic
702   book), only limited means were available to create an emotional connection between the
703   story's main character and the reader. Neither dialogue can be conveyed with typical comic
704   speech bubbles, nor should emotions in the animals be portrayed in a pronounced way.
705   Therefore, to bind the reader to the main character and create empathy, 'fictional' elements
706   of the so-called 'hero's journey' were used. At the beginning, the hero, a young
707   *Europasaurus*, lives comfortably under the care of the herd. A stroke of fate leaves the
708   protagonist on its own. The young animal must outgrow itself and continue on its way alone.
709   Although the course of this plot is fictional, it always remains realistic and plausible. For
710   example, a lightning strike as depicted killing the herd in our book is considered the most
711   plausible scientific explanation for the *Europasaurus* bone bed (Wings and Knüppe, 2020),
712   which contains remains of at least 21 individuals representing all ontogenetic stages (Scheil
713   and Sander 2017).

714

715 ## 2.7 Storytelling with pictures: How to find a unique style

716   From the beginning, a hybrid between comic book style and non-fiction book detailed
717   paleontological illustrations was planned. The square format of the book unfolds to double
718   pages in wide format. Each double page was used in full size for a basic illustration showing
719   a core message (Fig. 13A). In this basic illustration, small comic panels are placed that
720   either advance the plot or provide further insights into the ecosystem. Occasional text blocks
721   offer further information. We refrained from using a typical comic panel-to-panel structure on
722   a white background and the distinctive hand-lettered black font set in white speech bubbles
723   or boxes. Instead, all design elements were subordinated to the overall impression of the
724   double pages and later adapted for a visually balanced outcome (Fig. 13B).

725   Our goal during the course of the story was to display the broadest possible spectrum of
726   different color and light moods in order to present them in a visually interesting way,
727   reaching a length of around 140 pages (around 70 double pages).

728   Time of day, weather, landscape, and flora as well as the change from wide settings (such
729   as landscapes) to detailed representations of small animals were used to create constantly
730   new image themes in accordance with the storyline. The dramatic composition and
731   representation of the main elements of the story essentially controls how long the reader
732   stays in such a world of pictures, colors, and moods.

733   This principle becomes evident on the first 18 double pages (Fig. 14): We started with a
734   picture dominated by black, showing the earth from a distance during a sunrise (1). We

735   'open the curtain' and accompany a marine crocodyliform *Machimosaurus* on its journey

736   from the ocean (2–3) through a river delta (4) into the hinterland of an island. There in a lake,

737   the individual first fights (5–6) and then mates (7). On pages 2 and 3, deep blue tones depict

738   the ocean, which then gradually merge into green colors, illustrating the inland areas. The

739   mating takes place in the 'romantic' warm light of a sunset (7). The first seven double pages

740   illustrate the behavior of the *Machimosaurus* over the course of a day. During the night, the

741   small multituberculate mammal *Teutonodon* meets a sleeping (dying) *Machimosaurus* (8).

742   Now the focus switches to *Teutonodon*, and we accompany it on its prowl through the night

743   (9–11) until the mammal reaches its den, where it takes care of its offspring and falls asleep

744   among them (12–13). The nocturnal images are mostly implemented in close-up views with

745   detailed depictions. In contrast, the following dawning new day is introduced in a large wide-

746   angle landscape shot (14). The subsequent four double pages show the *Europasaurus* herd

747   near the mammalian den. The story continues on a sunny day in a light forest dominated by

748   green (plants) and yellow (ground) colors (15–18).

749   From the beginning, all images were planned and created to stand alone (i.e., without text) in

750   order to use the visual medium to its maximum effect. In some places where short

751   explanations could contribute to a better understanding of the storyline, reduced text was

752   added to the sequence of images in a final production step. The factual section following the

753   narrative graphic novel part explains the main scientific results of the *Europasaurus* Project

754   in an easily understandable way. Its bilingualism (German/English) ensures easy access of

755   an international audience to the background information.

756

757   2.8 How to maximize awareness: Social media and exhibitions

758   The book was published in November 2020. It contains 184 pages, 38 of which comprise the

759   scientific background. At the same time the book was published, social media activities on

760   various channels (Twitter, Instagram, Facebook, and YouTube) were started for promotion.

761   We also provided free access to half of the book's content on YouTube as animated motion

762   comic videos. In four episodes, short stories about different organisms in the ecosystem of

763   the time are told: episode 1 deals with the marine crocodyliform *Machimosaurus*, episode 2

764   with the small nocturnal mammal *Teutonodon*, episode 3 with *Europasaurus* and predatory

765   ceratosaurs, and episode 4 focuses on a natural disaster that probably took place at that

766   time and caused the mass occurrence of fossil bones. Each of the four videos is available in

767   English and German versions. The free online access helps to achieve a large international

768   distribution (link to the first English episode on YouTube: https://youtu.be/ftkxBgQJslM).

769   Beyond presentation in digital media, the detailed life restorations beg to be presented on a
770   larger scale in the context of exhibitions. Some *Europasaurus* works were already on display
771   in the special exhibition 'KinoSaurier' at the Lower Saxon State Museum Hannover,
772   Germany, and the Natural History Museum in Vienna, Austria. Overall, the responses to the
773   graphic novel have been very positive, and we hope that through our work we can also
774   contribute to a better understanding of prehistoric times in Germany.
775

2.9 Insights into the production process

777   A small team of people, whose different professions complemented each other, created the
778   graphic novel *EUROPASAURUS – Life on Jurassic Islands*. Vertebrate paleontologist Oliver
779   Wings, an expert on the fossil biota of the Langenberg locality including *Europasaurus*,
780   provided the scientific background. Paleoartist Joschua Knüppe illustrated press releases
781   about the newly described taxa from the Langenberg Quarry for several years, providing him
782   with a solid base of knowledge for this project. Knüppe created a total of 275 detailed
783   illustrations for the comic section and a further 80 illustrations for the factual section of the
784   book. Media designer and art director Henning Ahlers was responsible for the consistency of
785   the narrated story, done through 'visual storytelling' with a continuous arc of suspense and a
786   coherent color scheme. Museum educator Arila Perl took care of the design and typesetting
787   of the entire book. The creation of the book took a total of three years from the conception of
788   the first chapter to the final print. Up to two dozen versions of storyboards for the respective
789   storyline were created in advance before the final version of the illustrations were
790   implemented as elaborate acrylic paintings. Due to the spatial separation of the team, video
791   conferences were the primary form of communication. Even before the pandemic, these
792   online meetings took place several times a week.

793   After collecting ideas and determining a first rough plot, storyboard sketches were created
794   (mostly on brown paper) in order to precisely indicate the arrangement of light and shadow
795   (Fig. 15). These early storyboards served as the basis for further discussions to detail and
796   refine the story. Especially in the later developmental stages, traditional sketches were
797   combined with digital ones, allowing the team to witness and discuss their creation through
798   screen sharing.

799   Once the compositions and story of a section were finalized, the sketches were transferred
800   onto large paper. Each double page was painted in 58.5 x 29.5 cm format, larger than their
801   final book printing in order to ensure a higher detail density. During the early creation of the
802   chapters, the base coat of paint was applied with large brushes. However, this often led to

803 uneven color gradients and noticeable brushstrokes, especially with darker tones.
804 Eventually, we switched to the use of small synthetic sponges for the application of the first
805 layers of paint. On top of these, a rough sketch of the composition was drawn and the first
806 shapes of flora and fauna blocked in, starting with the scenery and ending with the main
807 focal points of the painting. Here, a mixture of gouache, acrylic paints, watercolors, and
808 colored pencils was used. After shapes and shadows were depicted, details like skin
809 patterns and textures were added. This later stage often went through a few discussions to
810 ensure consistent quality and effectiveness of the compositions. After the drawing stage was
811 complete, final digital high-resolution scans of the picture were produced accompanied by a
812 first rough color correction, retouches, and sometimes further digital enhancement. The final
813 step before publication consisted of detailed retouches (digitally removing dust particles,
814 etc.) as well as color and brightness corrections. The front flyleaf (Fig. 16) as well as two of
815 the double pages (Figs .17, 18) give examples of the final outcome.

816

817 3 Conclusion and Outlook

818 Since their scientific discovery almost 200 years ago, dinosaurs and other extinct taxa have
819 always inspired our imagination, and they will likely continue to do so in coming generations.
820 Their common appearance in pop culture provides an unparalleled opportunity for
821 transmitting paleontological research to the public. Projects like the *EUROPASAURUS – Life*
822 *on Jurassic Islands* graphic novel provide the means to correct common misconceptions of
823 fossil organisms, their interactions, and former ecosystems in the public eye.
824 Such publications also combine useful sources of information and fun in education. We hope
825 that our experiences may inspire others to create similar works on other paleontological
826 topics or even other disciplines of geoscience. This is further underlined by the past success
827 of comics about past worlds and their inhabitants, whether as adventure, illustrated science
828 book, or self-narrative documentary.
829

830 Data availability

831 Data were collected from the available comic and graphic novel literature. We acquired
832 permissions for the depicted images from the current copyright holders to the best of our
833 knowledge. Most works are still publicly accessible to purchase.

834

Author contributions

OW, JK, HA and JF conceptualized and designed the EUROPASAURUS graphic novel, AP carried out the typesetting of the book. OW and JF developed the idea for this article. JF provided the initial review of comics and graphic novels, JK the section on paleoart, AP the section about teaching science with graphic novels, OW, JK, HA wrote the section on the EUROPASAURUS graphic novel. JF, HA, JK, and OW prepared the figures for the article. OW, JF and SK designed the questionnaire which was evaluated by SK. OW and JF prepared the draft and edited several pre-publication manuscripts with contributions from all other authors.

Competing interests

The authors declare that they have no conflict of interest.

Acknowledgements

In preparing this article, considerable time was spent in obtaining the necessary permissions to reproduce copyrighted material in this open access article in order to allow the reader to experience the various comics with their merits and peculiarities. We sincerely hope that we have not overlooked any claims, and would like to thank the many people, artists, and publishers for further information and generous permissions to use their graphics in our article. We thank in alphabetical order: Anja Adam (Egmont Ehapa Media, Berlin), Verena Arzmiller (Carlsen Verlag, Munich), Matteo Bacchin (Milan), Mandy Barr (DC Comics, New York), Saskia Baumgart (Bulls Pressedienst, Frankfurt am Main), Bradford W. Berger (First Classics, Inc., Pioneertown), Meghan Chan and Kari Torson (Dark Horse Comics, Milwaukie), Ricardo Delgado (Los Angeles), Achim Dressler (Bocola Verlag, Klotten), Eckhard Friedrich (Bildschriftenverlag, Hannover), Tadd Galusha (Anchorage), Abby Howard (Charlotte), Irene Kahlau and Helga Uhlemann (Tessloff Verlag, Nürnberg), Mike Keesey (Los Angeles), Jim Lawson (Chesterfield), Robert Löffler (MOSAIK Steinchen für Steinchen Verlag, Berlin), Ted Rechlin (Rextooth Studios, Bozeman), Max Schlegel (Splitterverlag, Bielefeld), Mark Schultz (Clarks Summit), Stephanie Steinmetz [The Walt Disney Company (Germany), Munich], Stephen R. Bissette (Vermont), Rosemary Volpe and Erin Gredell (Peabody Museum of Natural History, Yale University), Rostislav Walica (Prague), Cathy

866   Wilbanks (Edgar Rice Burroughs, Inc., Los Angeles), and Nadine Winns (Abbeville Press,

867   New York).

868   Brian Andres (University College Birmingham) and Larry Rhinehart (Albuquerque) are

869   acknowledged for corrections and comments on earlier versions of this manuscript. Andreas

870   Stark (University Halle-Wittenberg) helped with the thematic analysis. We are grateful to the

871   editor John K. Hillier as well as the reviewers Jeff Liston (Royal Tyrrell Museum of

872   Palaeontology, Canada) and Victoria Coules (University of Bristol, UK) for their helpful

873   comments that put the final touches on the manuscript. Moreover, we thank the Volkswagen

874   Foundation for funding the *Europasaurus* Project and the creation of the graphic novel. The

875   Dinosaurier-Park Münchehagen, Nils Knötschke as well as Fabian and Janna von Pupka

876   supported and permitted our field work.

877

878

879   Copyright notices

899

900

Review statement

References

Abel, J. and Klein, C. (Eds.): Comics und Graphic Novels. Eine Einführung, J. B. Metzler Verlag, Stuttgart, 344 pp., 2016.

Allain, R., Vullo, R., Rozada, L., Anquetin, J., Bourgeais, R., Goedert, J., Lasseron, M., Martin, J. E., Pérez-García, A., Peyre de Fabrègues, C., Royo-Torres, R., Augier, D., Bailly, G., Gazes, L., Despres, Y., Gailliègue, A., Gomez, B., Goussard, F., Lenglet, T., Vacant, R., Mazan, Tournepiche, J.-F.: Vertebrate paleobiodiversity of the Early Cretaceous (Berriasian) Angeac-Charente Lagerstätte (southwestern France): implications for continental faunal turnover at the J/K boundary, Geodiversitas, 44 (25), 683–752, 2022.

Allison, R. H.: Not a Plastic Bag, Boom Entertainment, Los Angeles, 88 pp., 2012.

Augusta, J.: Divy prasvěta, Toužimský & Moravec, Prague: 754 pp., 1942.

Augusta, J. and Burian, Z.: Prehistoric Animals, London Spring Books: 152 pp, 1956.

Andrews, R. C.: On the trail of ancient man: a narrative of the field work of the Central Asiatic Expeditions, G. P. Putnam's Sons, New York & London: 370 pp, 1926.

Avery, K. J., Roque, O. R., Howat, J. K., Burke, D. B. and Voorsanger, C. H.: American Paradise: The World of the Hudson River School. Metropolitan Museum of Art, New York, 347 pp., 1987.

Bacchin, M. and Signore, M.: Dinosaurs: The Journey - *Plateosaurus*, Abbeville Kids, New York: 64 pp., 2008.

Berta, A.: Art revealing science: marine mammal palaeoart, Historical Biology, 33, 2897–2907, https://doi.org/10.1080/08912963.2020.1834541, 2021.

935 Bertagna, J. and Goldsmith, W.: John Muir, Earth. - Planet, Universe, Scottish Book Trust,
936 Edinburgh, 132 pp., 2014.

938 Bissette, S. R.: S. R. Bissette's Tyrant #1 - SpiderBaby Grafix & Publications, Wilmington, 32
939 pp., 1994.

941 Bissette, S. R.: The Paleo Path: Paleo and the History of Dinosaur Comics, in: The Collected
942 Paleo. Tales from the Late Cretaceous, edited by Lawson, J., Zeromayo Studios,
943 Northampton: 1–10, 2003.

945 Bölsche, W.: Tiere der Urwelt in 30 Kunstblättern nach wissenschaftlichem Material
946 bearbeitet. Serie Ia, Kakao-Compagnie Theodor Reichardt, Hamburg-Wandsbek: 30 pl,.
947 1916.

949 Bölsche, W.: Das Leben der Urwelt. Aus den Tagen der großen Saurier, Georg Dollheimer,
950 Leipzig: 348 pp., 1931.

952 Brremaud, F. and Bertolucci, F.: Love: The Dinosaur, Magnetic Press, Portland, 80 pp.,
953 2017.

955 Carlin, G. and Foster, H.: Edgar Rice Burroughs' Tarzan: The Sunday Comics, 1931-1933
956 Volume 1, Dark Horse Books, Milwaukee, 120 pp., 2013.

958 Carballido J. L. and Sander P. M.: Postcranial axial skeleton of *Europasaurus holgeri*
959 (Dinosauria, Sauropoda) from the Upper Jurassic of Germany: implications for sauropod
960 ontogeny and phylogenetic relationships of basal Macronaria. J Syst Palaeontol, 12, 335–
961 387, https://doi.org/10.1080/14772019.2013.764935, 2014.

963 Carballido, J. L., Scheil, M., Knötschke. N. and Sander. P. M.: The appendicular skeleton of
964 the dwarf macronarian sauropod *Europasaurus holgeri* from the Late Jurassic of Germany
965 and a re-evaluation of its systematic affinities, J Syst Palaeontol., 18, 739–781, 2020.

967 ComicSelection: Drachen und Saurier in unseren Comics. Urzeit-Monster Jahrzehnte vor
968 Jurassic Park, C. Kuhlewind Verlag, Bergisch Gladbach, 199 pp., 2019.

970 Cox, B., Savage, R. J. G., Gardiner, B. and Dixon, D.: Illustrated Encyclopedia of Dinosaurs
971 and Prehistoric Animals, Macmillan, London, 312 pp., 1988.

972

973 Czerkas, S.: Cine-Saurus. The History of Dinosaurs in the Movies, The Dinosaur Museum,
974 Blanding, 93 pp., 2006.

975

976 Czerkas, S. J. and Czerkas, S. A.: Dinosaurs - A Global View, Collins & Brown, London, 248
977 pp., 1990.

978

979 Czerkas, S. J. and Olsen, E. C.: Dinosaurs Past and Present - Volume I & II, Natural History
980 Museum of Los Angeles County & University of Washington Press, 161 pp & 149 pp., 1987.

981

982 Czerkas, S. M. and Glut, D. F.: Dinosaurs, Mammoths, and Cavemen. The Art of Charles R.
983 Knight, E. P. Dutton, New York, 120 pp., 1982.

984

985 D'Ami, R. D.: Bunter Kinder-Kosmos. Tiere der Ur- und Vorzeit, Franckh'sche
986 Verlagshandlung, Stuttgart, 61 pp., 1973.

987

988 Dávila, C.: Luz Sees the Light, Kids Can Press, Toronto, 96 pp., 2011.

989

990 Delgado, R.: Age of Reptiles – Omnibus, Dark Horse Books, Milwaukee, 398 pp., 2011.

991

992 Delgado, R.: Age of Reptiles - Ancient Egyptians, Dark Horse Books, Milwaukee, 136 pp.,
993 2015.

994

995 DuBois, G. and Thompson, R. P.: Tarzan – the Jesse Marsh Years. Omnibus Volume 1,
996 Dark Horse Books, Milwaukee, 70 pp., 2017.

997

998 Evers S. W. and Wings, O.: Late Jurassic theropod dinosaur bones from the Langenberg
999 Quarry (Lower Saxony, Germany) provide evidence for several theropod lineages in the
1000 central European archipelago. PeerJ, 8, e8437. https://doi.org/10.7717/peerj.8437, 2020.

1001

1002 Farinella, M.: The potential of comics in science communication, Journal of Science
1003 Communication JCOM, 17 (01), Y01. https://doi.org/10.22323/2.17010401, 2018.

1004

1005 Fastnacht, M.: The first dsungaripterid pterosaur from the Kimmeridgian of Germany and the
1006 biomechanics of pterosaur long bones, Acta Palaeontol. Pol., 50, 273–288, 2005.

1007

Ferri, J.-Y. and Conrad, D.: Asterix and the Griffin, Little, Brown Book Group, Boston, 48 pp., 2021.

Flammarion, C.: Le Monde Avant La Creation de L'Homme: Origines de La Terre, Origines de La Vie, Origines de L'Humanite, Paris, 847 pp., 1886.

Galle, H. J.: Dinosaurier in Literatur, Comic und Film von den Anfängen bis 1975, Fantasia, 82/83, 236 pp., 1993.

Galusha, T.: Cretaceous, Oni Press, Portland, 160 pp., 2019.

Gaudin, J.-C., Barbaud, J. and Hadjiyannakis, A.: Es war einmal… der Mensch. Die Urzeit, Splitter Verlag, Bielefeld, 48 pp., 2021.

Gerke, O. and Wings, O.: Multivariate and cladistic analyses of isolated teeth reveal sympatry of theropod dinosaurs in the Late Jurassic of Northern Germany, PLoS One, 11(7), e0158334, https://doi.org/10.1371/journal.pone.0158334, 2016.

Germann, J. C.: From Rock to Canvas, Natural History, April, 166–175, 1943.

Glut, D. F. and Brett-Surman, M. K.: Dinosaurs in the Media, in: The Complete Dinosaur, edited by: Farlow, J. O. and Brett-Surman, M. K., Indiana University Press, Bloomington, 675–706, 1997.

Glut, D. F.: Dinosaurs in Comics, in: The Dinosaur Scrapbook, edited by Glut, D. F., Citadel Press, Secaucus, 189–235, 1980.

Gould, S. J.: Reconstructing (and Deconstructing) the Past, in: The Book of Life, edited by: Gould, S. J., Ebury Hutchinson/Random House UK Limited, London, 6–21, 1993.

Gould, S. J.: Foreword: Life Through Our Ages, in: Life through the Ages. Commemorative edition, edited by: Knight, C. R., Indiana University Press, Bloomington, vii–x, 2001.

Hallett, M.: Bringing dinosaurs to life, in: Dinosaurs Past and Present - Volume I, edited by: Czerkas, S. J. and Olsen, E. C, Natural History Museum of Los Angeles County & University of Washington Press, 96–113, 1987.

1045   Harder, J.: Alpha …Directions, Carlsen, Hamburg, 352 pp., 2010.

1046

1047   Harris, J. and Morazzo, M.: Great Pacific Volume 1: Trashed!, Image Comics, Portland, 144

1048   pp., 2013.

1049

1050   Hegen, H.: Expedition zum Urmeer. Die Digedags, Weltraum-Serie #6, Tessloff Verlag,

1051   Nürnberg, 100 pp., 2004.

1052

1053   Hegen, H.: Die Erfindung der Postrakete. Die Digedags, Weltraum-Serie #7, Tessloff Verlag,

1054   Nürnberg, 148 pp., 2006.

1055

1056   Hergé: Les aventures de Tintin - Le Sceptre d'Ottokar, Casterman, Tournai, 64 pp., 1947.

1057

1058   Holtz, T. R. Jr.: Dinosaurs. The Most Complete, Up-to-Date Encyclopedia for Dinosaur

1059   Lovers of All Ages, Random House, New York, 432 pp., 2007.

1060

1061   Hogarth, B.: Edgar Rice Burroughs Tarzan - versus the Nazis, Titan Books, London, 176 pp.,

1062   2016.

1063

1064   Holtz, T. R. Jr.: Dinosaurs: The Most Complete, Up-To-Date Encyclopedia for Dinosaur

1065   Lovers of All Ages, Random House, New York, 427 pp., 2007.

1066

1067   Hosler, J., Cannon, K. and Cannon, Z.: Evolution: The Story of Life on Earth, Hill & Wang,

1068   New York, 160 pp., 2011.

1069

1070   Howard, A.: Earth Before Us: Dinosaur Empire!, Amulet Books, New York, 126 pp., 2017.

1071

1072   Howard, A.: Earth Before Us: Ocean Renegades!, Amulet Books, New York, 124 pp., 2018.

1073

1074   Howard, A.: Earth Before Us: Mammal Takeover!, Amulet Books, New York, 124 pp., 2019.

1075

1076   Hübner, T.: Saurier – Die Erfindung der Urzeit, Schnell & Steiner, Regensburg, 176 pp.,

1077   2020.

1078

1079   Janzen, D.: Vom Fossil zum Bild. Künstlerische Darstellungen prähistorischen Lebens,

1080   Deutscher Kunstverlag, Berlin, 287 pp, 2020.

1081

1082 Kahlert, J.: Ganzheitlich Lernen mit allen Sinnen? Plädoyer für einen Abschied von
1083 unergiebigen Begriffen, Grundschulmagazin, 12/2000, 37–40, 2000.

1085 Kieser, J.: Fix und Fax. Gesammelte Abenteuer Band 7, MOSAIK Steinchen für Steinchen
1086 Verlag, Berlin, 95 pp., 2018.

1088 Klein, A.: EXPOSITUM - Zum Verhältnis von Ausstellung und Wirklichkeit, transcript Verlag,
1089 Bielefeld, 220 pp., 2004.

1091 Knight, C. R.: Before the Dawn of History, McGraw-Hill, New York, 119 pp., 1935.

1093 Knight, C. R.: Parade of Life through the Ages, The National Geographic Magazine, 81 (2),
1094 141–184, 1942.

1096 Knight, C. R.: Life through the Ages, Alfred A. Knopf, New York, 68 pp., 1946.

1098 Knight, C. R.: Animal anatomy and psychology for artists and laymen, McGraw-Hill, New
1099 York, 149 pp., 1947.

1101 Knipe, H. R.: Nebula to Man, J. M. Dent & Co., London, 251 pp., 1905.

1103 Kurlansky, M. and Stockton, F.: World Without Fish, Turtleback Books, Burnsville, 208
1104 pp.,2014.

1106 Lallensack, J.N., Sander, P.M., Knötschke, N. and Wings, O.: Dinosaur tracks from the
1107 Langenberg Quarry (Late Jurassic, Germany) reconstructed with historical photogrammetry:
1108 evidence for large theropods soon after insular dwarfism, Palaeontol. Electron., 18.2(31A),
1109 1–34, 2015.

1111 Lawson, J.: Paleo: The Complete Collection, Dover Publications, New York, 391 pp., 2016.

1113 Leidner, R.: Die Begriffe Barrierefreiheit, Zugänglichkeit und Nutzbarkeit, in: Das
1114 barrierefreie Museum – Theorie und Praxis einer besseren Zugänglichkeit. Ein Handbuch,
1115 edited by: Föhl, P. S., Erdrich, S., John, H. and Maaß, transcript Verlag, Bielefeld, 28–33,
1116 2007.

1118 Lescaze, Z.: Paleoart. Visions of the Prehistoric Past, Taschen, Cologne, 292 pp., 2017.

Life: Two Billion Years of Evolution, The World We Live In, #V, 7, September 1953, 64–70, 1953.

Liston, J. J.: 2000 A.D. and the new „Flesh": first to report the dinosaur renaissance in "moving" pictures, Geological Society Special Publication, 343, 335–360, 2010.

Long, R. A. and Houk, R. Dawn of the Dinosaurs: The Triassic in Petrified Forest. Petrified Forest Museum Assn, 96 pp., 1988.

Manucci, F. and Romano, M.: Reviewing the iconography and the central role of 'paleoart': four centuries of geo-palaeontological art, Historical Biology, https://doi.org/10.1080/08912963.2021.2017919, 2022.

Marpmann, J.S., Carballido, J.L., Sander, P.M. and Knötschke, N.: Cranial anatomy of the Late Jurassic dwarf sauropod *Europasaurus holgeri* (Dinosauria, Camarasauromorpha): ontogenetic changes and size dimorphism, J Syst Palaeontol, 13, 221–263, https://doi.org/10.1080/14772019.2013.875074, 2015.

Martin, T., Schultz, J.A., Schwermann, A.W. and Wings, O.: First Jurassic mammals of Germany: multituberculate teeth from Langenberg Quarry (Lower Saxony), Acta Palaeontol. Pol., 67, 171–179, https://doi.org/10.4202/pp.2016.67_171, 2016.

Martin, T., Averianov, A. O., Jäger, K. R. K., Schwermann, A. W. and Wings, O.: A large morganucodontan mammaliaform from the Late Jurassic of Germany, Foss. Impr., 75, 504–509, 2019.

Martin, T., Averianov, A. O., Schultz, J.A., Schwermann, A. W. and Wings, O.: Late Jurassic multituberculate mammals from Langenberg Quarry (Lower Saxony, Germany) and palaeobiogeography of European Jurassic multituberculates, Hist. Biol., 33 (5), 616–629, https://doi.org/10.1080/08912963.2019.1650274, 2021a.

Martin, T., Averianov, A. O., Schultz, J.A., Schwermann, A. W. and Wings, O.: A derived dryolestid mammal indicates possible insular endemism in the Late Jurassic of Germany, Sci. Na., 108: 23, 12pp., https://doi.org/10.1007/s00114-021-01719-z, 2021b.

1155   Mazan, Dethan, I., Allain, R. and Tounepiche, J.-F.: Mimo on the dinosaur trail, Eidola
1156   Editions, Angoulême, 66 pp., 2016.

1157

1158   McCloud, S.: Understanding Comics: The Invisible Art, HarperCollins Publishers, New York,
1159   216 pp., 1993.

1160

1161   McCloud, S.: Making Comics: Storytelling Secrets of Comics, Manga and Graphic Novels,
1162   HarperCollins Publishers, New York, 264 pp., 2006.

1163

1164   Merkl, U.: Dinomania: The Lost Art of Winsor McCay, the Secret Origins of King Kong, and
1165   the Urge to Destroy New York, Fantagraphics Books, Seattle, 295 pp., 2015.

1166

1167   Metzger, F.: Inklusion im Museum, in: Handbuch Museumspädagogik – Kulturelle Bildung in
1168   Museen, edited by: Commandeur, B., Kunz-Ott, H. and Schad, K., kopaed, München, 285–
1169   289, 2016.

1170

1171   Milner, R.: Charles R. Knight. The artist who saw through time, Abrams, New York, 180 pp.,
1172   2012.

1173

1174   Murray, W.: Verschwundene Welten & Farbfilm Kreaturen, Starlog Dinosaurier Magazin, 46–
1175   54, 1993.

1176

1177   Murray, W.: The Art of Dinosaurs, Starlog Dinosaur, 38–56, 1997.

1178

1179   Müller, O. and Walica, R.: Pravěký svět Zdeňka Buriana. Od vzniku Země po zánik
1180   dinosaurů, Albatros, Praha, 599 pp., 2022.

1181

1182   Nathan, D. L. and Crafton, D.: The Making and Re-making of Winsor McCay's *Gertie* (1914),
1183   Animation: An Interdisciplinary Journal, 8 (1), 23–46, 2013.

1184

1185   Norman, D.: When Dinosaurs ruled the Earth, Marshall Cavendish Limited, London, 80 pp.,
1186   1985.

1187

1188   Norman, D.: The Illustrated Encyclopedia of Dinosaurs: An Original and Compelling Insight
1189   into Life in the Dinosaur Kingdom, Salamander Books, London, 185 pp., 1988.

1190

1191   Paul, G. S.: The Art of Charles R. Knight, Scientific American, 274 (6), 86–93, 1996.

1192

1193   Prokop, V.: Zdeněk Burian, Gallery, Praha, 224 pp., 2005.

1194

1195   Rechlin, T.: Tyrannosaurus Rex, Rextooth Studios, Bozeman, 96 pp., 2016.

1196

1197   Rechlin, T.: T rex Generations, Rextooth Studios, Bozeman, 96 pp., 2018.

1198

1199   Rechlin, T.: SUE: Welcome to the World of Tyrannosaurus Rex, Rextooth Studios,

1200   Bozeman, 120 pp., 2019.

1201

1202   Reed, A. H., Henry, R. J. and Mason, W. B. Influence of statistical method used on the

1203   resulting estimate of normal range, Clinical Chemistry, 17: 275–284,

1204   https://doi.org/10.1093/clinchem/17.4.275, 1971.

1205

1206   Reed, M. K. and Flood, J.: Science Comics: Dinosaurs – Fossils and Feathers, First Second,

1207   New York, 128 pp., 2016.

1208

1209   Reich, M., Krings, M., Jovanovic-Kruspel, S. and Fischer, J.: Paleo-art in the early 20th

1210   century, in: CineSaurs. Fiction & Science, edited by: Mair. A., Göhlich, U. B., Richter, A.,

1211   Hercenberger, D. and Kroh, A., Natural History Museum Vienna, Vienna, 30–34, 2021.

1212

1213   Richter, A., Knötschke, N., Kosma, R., Sobral, G. and Wings, O.: The first Mesozoic lizard

1214   from northern Germany (Paramacellodidae, Late Jurassic, Langenberg Quarry) and its

1215   taphonomy, Program and Abstracts, Society of Vertebrate Paleontology 73rd Annual

1216   Meeting, October 30 —November 2, 2013, Los Angeles, Supplement to the online J.

1217   Vertebr. Paleontol., October 2013: 198, 2013.

1218

1219   Ross, S. R. M., Duggan-Haas, D. and Allmon, W. D.: The posture of *Tyrannosaurus rex*:

1220   Why do student views lag behind the science?, Journal of Geoscience Education, 61: 145–

1221   160, 2013.

1222

1223   Sadecký, P.: Zdeněk Burian's abenteuerloses Leben. No. 2 der Monographie in 5 Teilen,

1224   IPCRESS-ITA Verlag, Bonn, 62 pp., 1982a.

1225

1226   Sadecký, P.: Zdeněk Burian contra Frank Frazetta, Teil A. Ergänzungsband (No. 6) der

1227   Monographie in 5 Teilen, IPCRESS-ITA Verlag, Bonn, 48 pp., 1982b.

1228

1229 Sander, P.M., Mateus, O., Laven, T. and Knötschke, N.: Bone histology indicates insular
1230 dwarfism in a new Late Jurassic sauropod dinosaur, Nature, 441, 739–741,
1231 https://doi.org/10.1038/nature04633, 2006.

1233 Sax, D.: The revenge of analog: Real things and why they matter. Public Affairs, New York,
1234 292 pp., 2016.

1236 Scheele, W. E.: Ancient Elephants, The World Publishing Company, New York, 64 pp.,
1237 1958.

1239 Scheil, M. and Sander, P. M.: Ein Zwerg unter Riesen: Der sauropode Dinosaurier
1240 *Europasaurus* und seine Evolution und Lebensweise. Jurassic Harz: Dinosaurier von Oker
1241 bis Wyoming, edited by: Hühne, C., Verlag Dr. Friedrich Pfeil, München, 49–56, 2017.

1243 Schwarz, D., Raddatz, M. and Wings, O.: *Knoetschkesuchus langenbergensis* gen. nov. sp.
1244 nov., a new atoposaurid crocodyliform from the Upper Jurassic Langenberg Quarry (Lower
1245 Saxony, northwestern Germany), and its relationships to *Theriosuchus*, PLoS One,
1246 12:e0160617, https://doi.org/10.1371/journal.pone.0160617, 2017.

1248 Schleiter, K. D.: MOSAIK Sammelband 54: Der Hexenprozess, MOSAIK Steinchen für
1249 Steinchen Verlag, Berlin, 120 pp., 2011.

1251 Schultz, M.: Xenozoic, Flesk publications, Santa Cruz, 352 pp., 2013.

1253 Short, J. C. and Reeves, T. C.: The Graphic Novel: A "cool" Format for communicating to
1254 Generation Y, Business Communication Quarterly, 71 (4), 414–430, 2009.

1256 Spindler, F.: Paläoart - Die Kunst, durch die Zeit zu reisen, in: Saurier - Die Erfindung der
1257 Urzeit, edited by: Hübner, T. - Schnell & Steiner, Regensburg, 144–157, 2020.

1259 Squaronzi, P. and Whittington-Evans, N.: Climate Changed: A Personal Journey Through
1260 the Science, Abrams ComicArts, New York 473 pp., 2014.

1262 Stout, W.: The Dinosaurs, Bantam Doubleday Dell Publishing Group, New York, 160 pp.,
1263 1981.

1265 Štorch, E.: Lovci mamutů, Toužimský & Moravec, Praha, 292 pp., 1937.

1266

1267 Spiegel, A. N., McQuillan, J., Halpin, P., Matuk, C. and Diamond, J.: Engaging teenagers

1268 with science through comics. Res. Sci. Educ., 43, 2309–2326,

1269 https://doi.org/10.1007/s11165-013-9358-x, 2013.

1270

1271 Spinar, Z. V.: Life before Man, Thames & Hudson Ltd., London, 228 pp., 1972.

1272

1273 Tatalovic, M.: Science comics as tools for science education and communication: a brief,

1274 exploratory study, Journal of Science Communication *JCOM,* 8 (4), A02,

1275 https://jcom.sissa.it/archive/08/04/Jcom0804%282009%29A02, 2009.

1276

1277 Volpe, R.: The Age of Reptiles. The Art and Science of Rudolph Zallinger's Great Dinosaur

1278 Mural at Yale, 2nd ed., Peabody Museum of Natural History, Yale University, New Haven, 76

1279 pp., 2007.

1280

1281 Walica, R.: Dinosauria Buriannica. The Burianian phenomenon - Searching for a context.

1282 Part I, Prehistoric Times, 58 (1), 28–31.

1283

1284 Watson, J. W.: Prehistoric Animals: Dinosaurs and other Reptiles and Mammals, Simon &

1285 Schuster, New York, 56 pp., 1960.

1286

1287 Watterson, B.: The Complete Calvin and Hobbes, Andrews McMeel Publishing, Kansas City,

1288 1440 pp., 2012.

1289

1290 White, S.: Dinosaur Art: The World's Greatest Paleoart, Titan Books, London, 188pp, 2012.

1291

1292 Wilson, W. O.: "Madge the Magician's Daughter" Classic Comic Collection, CreateSpace

1293 Independent Publishing Platform, 60 pp., 2010.

1294

1295 Wings, O. and Knüppe, J.: EUROPASAURUS – Urzeitinseln voller Leben/Life on Jurassic

1296 Islands, Verlag Dr. Friedrich Pfeil, München, 184 pp., 2020.

1297

1298 Wings O. and Sander, P. M.: The Late Jurassic vertebrate assemblage of the Langenberg

1299 Quarry, Oker, Northern Germany, Fundamental, 20, 281–284, 2012.

1300

1301 Witton, M. P.: The Palaeoartist's Handbook. Recreating Prehistoric Animals in Art, Crowood,

1302 Ramsbury, 224 pp., 2018.

1303

1304   Witton, M. P.: Life through the Ages. Twenty-first Century Visions of Prehistory, Indiana

1305   University Press, Bloomington, 156 pp., 2020.

1306

1307   Wolf, J.: Menschen der Urzeit, Artia, Praha, 231 pp., 1977.

1308

1309   Wong, S. W. L., Miao, H., Cheng, R. W.-Y. and Yip, M. C. W.: Graphic Novel

1310   Comprehension Among Learners with Differential Cognitive Styles and Reading Abilities,

1311   Reading & Writing Quarterly, 33 (5), 1–16, 2016.

1312

1313   Yang, G.: Graphic Novels in the Classroom, Language Arts, 85 (3), 185–192, 2008.

1314

1315   Zallinger, R.: Dinosaurs. Brooke Bond Album 5, Brooke Bond Canada Limited, Toronto, 30

1316   pp., 1966.

1317

1318   Zuo, F., Heimhofer, U., Huck, S., Luppold, F. W., Wings, O. and Erbacher, J.: Sedimentology

1319   and depositional sequences of a Kimmeridgian carbonate ramp system, Lower Saxony

1320   Basin, Northern Germany, Facies, 64 (1). https://doi.org/10.1007/s10347-017-0513-0, 2018.

1321

1322

Figure captions

Figure 1: Themes of great paleo-artists and their mirror images in comics: (**a**) Charles R. Knight's classic *Triceratops* from 1928 (© Field Museum of Natural History, Chicago) and its comic counterpart in *Turok, Son of Stone* #10, December–February 1957–1958; (**b**) Rudolph Zallinger's iconic *Tyrannosaurus* from the 1947 mural "The Age of Reptiles" (© Yale Peabody Museum of Natural History, New Haven) and its comic counterpart in *Turok, Son of Stone* #3, March–May 1956; (**c**) Zdeněk Burian's famous *Stegosaurus* from 1941 (© Charles University, Faculty of Science, Prague) and its comic counterpart in *Turok, Son of Stone* #16, June–August 1959. (Turok, Son of Stone™ & © Penguin Random House, Inc. Under license to Classic Media, LLC). All rights reserved.

Figure 2: Adventure Stories I: (**a**) a sauropod-like dinosaur in Windsor McCay's *Dream of the Rarebit Fiend*, May 25, 1913, which already displays behaviors of McCay's 1914 animated *Gertie the Dinosaur* (Public Domain); (**b**) the awakening of 'Knightian' dinosaur incarnations in *Madge the Magician's Daughter* by W. O. Wilson in 1907 (Public Domain); (**c**) the clash of Tarzan with a colorful 'Knightian' *Tyrannosaurus* in Harold Foster's *Edgar Rice Burrough's Tarzan*, October 23, 1932 (© 1932, 2022 Edgar Rice Burroughs, Inc. Tarzan®, Edgar Rice Burroughs® Owned by Edgar Rice Burroughs, Inc. and used by permission); (**d**) several Knight-inspired predatory dinosaurs in Jesse Marsh's *Tarzan Comic* #16, July–August 1950 (© 1950, 2017, 2022 Edgar Rice Burroughs, Inc. Tarzan®, Edgar Rice Burroughs® Owned by Edgar Rice Burroughs, Inc. and used by permission.). All rights reserved.

Figure 3: Adventure Stories II: (**a**) the explosive clash between dinosaurs and American soldiers during WWII in *Star-Spangled War Stories* #96, May 1961 (© 2022 DC Comics); (**b**) an inauspicious encounter between a *Styracosaurus* and protagonist Jack's Cadillac in the cataclysmic world of Mark Schultz *Xenozoic Tales* #9, September 1989 (Xenozoic™ & © 2022 Mark Schultz); (**c**) "Forbidden Valley", Carl Barks' version of a Lost World, that Donald and his nephews experience firsthand in *Walt Disney's Donald Duck* #54, July–August 1957 (© 2022 Disney); (**d**) the diverse prehistoric era in the 1974 time-travel adventure of *Fix und Fax* #193 (© Jürgen Kieser / 2022 MOSAIK Steinchen für Steinchen Verlag). All rights reserved.

Figure 4: Adventure stories III: (**a**) the Abrafaxe experience rough manners in the Cretaceous in *Mosaik* #216, December 1993 (© 2022 MOSAIK – Die Abrafaxe); (**b**) in 50 B.C. the Gauls and Romans, who are always at clinch, meet a frozen Burian'esque

Styracosaurus in *Asterix* #39, 2021 (ASTERIX®- OBELIX®- IDEFIX® & © 2022 LES EDITIONS ALBERT RENE, in the German speaking area published by Egmont Ehapa Media). All rights reserved.

Figure 5: Adventure stories supported by educational information: (**a**) a classic Zallinger *Tyrannosaurus* attacks the two main characters in *Turok, Son of St*one #10, December–February 1957–1958 (Turok, Son of Stone™ & © Penguin Random House, Inc. Under license to Classic Media, LLC); (**b**) a *Young Earth* paleo story without human characters supplements *Turok, Son of Stone* in #12, June–August 1958 (Turok, Son of Stone™ & © Penguin Random House, Inc. Under license to Classic Media, LLC); (**c**) on an alien planet, the Digedags find living 1950's dinosaurs in *Mosaik* by Hannes Hegen # 62, January 1962 (© 2006 Tessloff Verlag); (**d**) dinosaur as shadow plays in the memories of survivors of the Cretaceous apocalypse in Mike Keesey's *Paleocene* #1, 2020 (© 2022 Mike Keesey). All rights reserved.

Figure 6: Adventure stories supported by sophisticated educational information: (**a**) not everything was better in the past, as an excerpt from Cretaceous life in Jim Lawson's *Paleo* vividly shows (© 2016 Jim Lawson); (**b**) even *Tyrannosaurus* didn't always have it easy in Ted Rechlin's *Tyrannosaurs rex* (© 2016 Ted Rechlin);Self-narrative storyboards: (**c**) textless telling of impressive-dynamic dinosaur stories in Ricardo Delgado's *Age of Reptiles* narrative "Tribal Warfare" 1993 (Age of Reptiles™ & © 2022 Ricardo Delgado); (**d**) a creative use of panels is used by Tadd Galusha in *Cretaceous* in 2019 to tell the textless story (Cretaceous™ & © 2019 Tadd Galusha). All rights reserved.

Figure 7: Comic science books: (**a**) large-format comic-style illustrations with concise text blocks in plain language can be found in *Classics Illustrated Special #167A*, 1962 (Classics Illustrated™ & © First Classics, Inc.); (**b**) comic-like realization of the French animated series Once *Upon a Time... Man*, with all the quirks and loveliness that made the original so unique (© 2022 Soleil Productions / Splitter Verlag / Jean-Charles Gaudin / Jean Barbaud); (**c**) evolutionary process of conquering airspace by pterosaurs as a graphically homogenized collage of cultural images of early aviation, mythological flying creatures as well as schematic paleontological depictions including old as well as more recent reconstructions in Jens Harder's *Alpha ...Directions* (© 2010 Carlsen Verlag); (**d**) creative and at the same time comprehensive knowledge transfer on paleontological topics succeeds Abby Howard in her *Earth Before Us* book series #1 "Dinosaur Empire!" (© 2017 Abby Howard). All rights reserved.

Figure 8: Genre potpourri: (**a**) dynamic storytelling illuminates the story of the egg thief dinosaur *Chirostenotes* in *S.R. Bissette's Tyrant* #1, 1994 (*S.R. Bissette's Tyrant*® is a registered trademark of Stephen R. Bissette; *Tyrant*® story and art © 1994, 2022 Stephen R. Bissette); (**b**) a look at the diverse living world of the Triassic in Matteo Bacchin and Marco Signore's *Dinosaurs* #1 "The Journey: *Plateosaurus*", 2008 (© 2008 Matteo Bacchin / Marco Signore). All rights reserved.

Figure 9: Infographics visualizing the main results of the online survey. For details see main text.

Figure 10: Comparison between paintings that influenced the EUROPASAURUS graphic novel and one of its final double page's creations.
(**a**) *Der Abend*, Caspar David Friedrich (1821), Public Domain; (**b**) *Twilight Wilderness*, Frederic Edwin Church (1860), Public Domain; (**c**) Juvenile *Europasaurus* in the Evening, artwork by Joschua Knüppe (2020), EUROPASAURUS graphic novel, page 116-117 (© Wings & Knüppe 2020).

Figure 11: Comparison between paintings that influenced the EUROPASAURUS graphic novel and one of its final double page's creations.
(**a**) *California Sunset*, Albert Biertstadt, undated, Public Domain; (**b**) *Figures in Hudson River Landscape*, Albert Bierstadt, undated, Public Domain; (**c**) *Moonlit Landscape*, Albert Bierstadt, undated, Public Domain; (**d**) *Pterosaurs over the Sea*, artwork by Joschua Knüppe (2019), EUROPASAURUS graphic novel, page 76-77 (© Wings & Knüppe 2020).

Figure 12: Comparison between paintings that influenced the EUROPASAURUS graphic novel and one of its final double page's creations.
(**a**) *Staffa, Fingal's Cave*, William Turner, undated, Public Domain; (**b**) *Fishermen at Sea*, William Turner (1796), Public Domain; (**c**) *Northeaster*, Winslow Homer (1895), Public Domain; (**d**) *Storm over the Jurassic Sea*, artwork by Joschua Knüppe (2019), EUROPASAURUS graphic novel, page 74-75 (© Wings & Knüppe 2020).

Figure 13: (**a**) Example of a final double page in the book; (**b**) Schematic structure of this double page: The structure of the basic illustration and the movement of the *Europasaurus*

herd correspond to the usual "western" reading direction from left to right. The reader starts in the familiar way of looking at the top left and following the diagonal direction of action across the center of the picture to the bottom right (1). As graphical compensation, two inset panels were placed at the bottom left, which in turn are set from left to right in their reading direction (2). The left panel is placed behind the right panel, supporting the desired reading order. The panels illustrate a detail as well as another perspective of the action in the basic illustration. When designing double pages, it is always important to ensure that the area in the middle of the picture does not contain crucial information, as this might otherwise be lost during binding of the book (3). The text block in the upper right corner (4) provides additional graphic balance. The necks of the sauropods point up to the text block. They represent the last element in the sequence of perception on the double page. The text offers additional information about the action of the herd action, namely their motivation. Horizontal lines, resulting from the surf, the beach and the tree line, stabilize the overall presentation of the double page with its otherwise diagonal impression (© Wings & Knüppe 2020).

Figure 14: The color scheme of the first 18 double pages of the book. Changing the dark distance view at the beginning into deep blue, and later green colors. A warm sunset light closes the first day, followed by dark night scenes. The second day starts again with warm colors, whereas green and yellow dominates the landscapes on the following pages. For more explanation, see main text (© Wings & Knüppe 2020).

Figure 15: The evolution of storyboard sketches sometimes included many different versions for a particular scene. This double page combines the end of a turtle hatchling storyline with the introduction of (swimming) torvosaurid theropods (© Wings & Knüppe 2020).

Figure 16: The front flyleaf of the book introduces all larger vertebrates in the same scale (© Wings & Knüppe 2020).

1458 **Figure 17**: This double page shows *Europasaurus* individuals during feeding on the shore.

1459 One individual is feeding on kelp which offered the opportunity to show some of the shallow

1460 marine organisms too (© Wings & Knüppe 2020).

1461

1462 **Figure 18**: This double page shows the juvenile *Europasaurus* moving through a horse tail

1463 forest. Some eupterodactyloid pterosaurs are hitching a ride (© Wings & Knüppe 2020).

1464

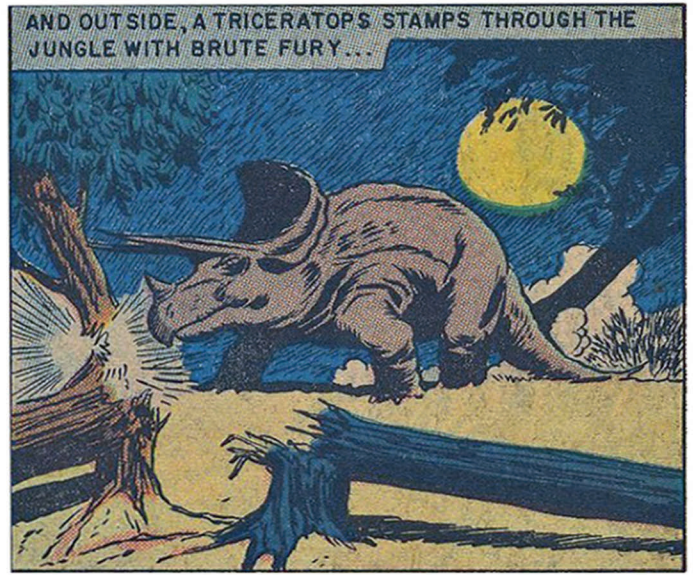
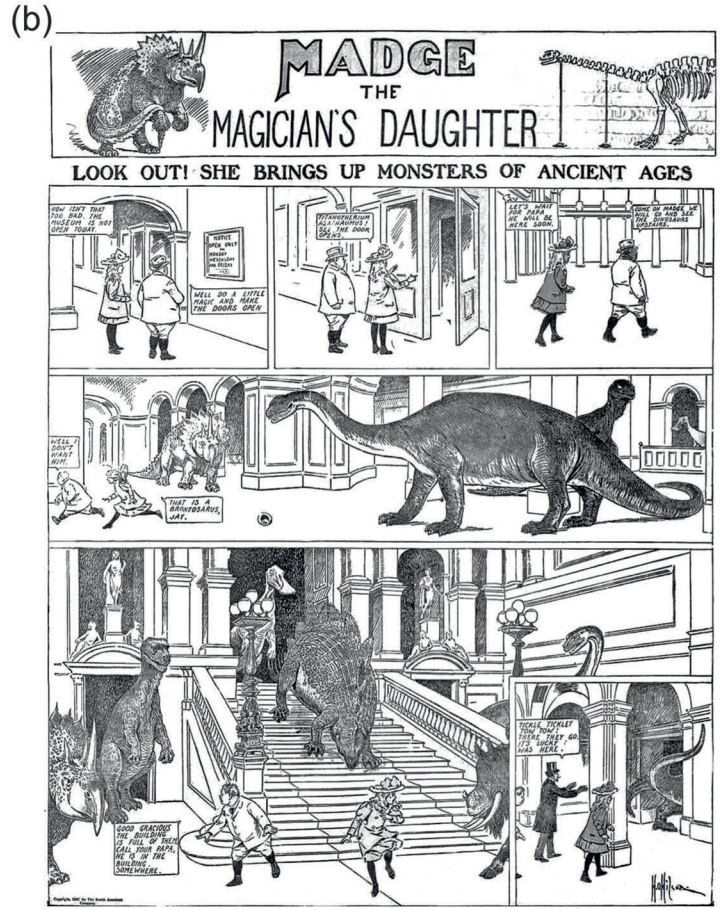
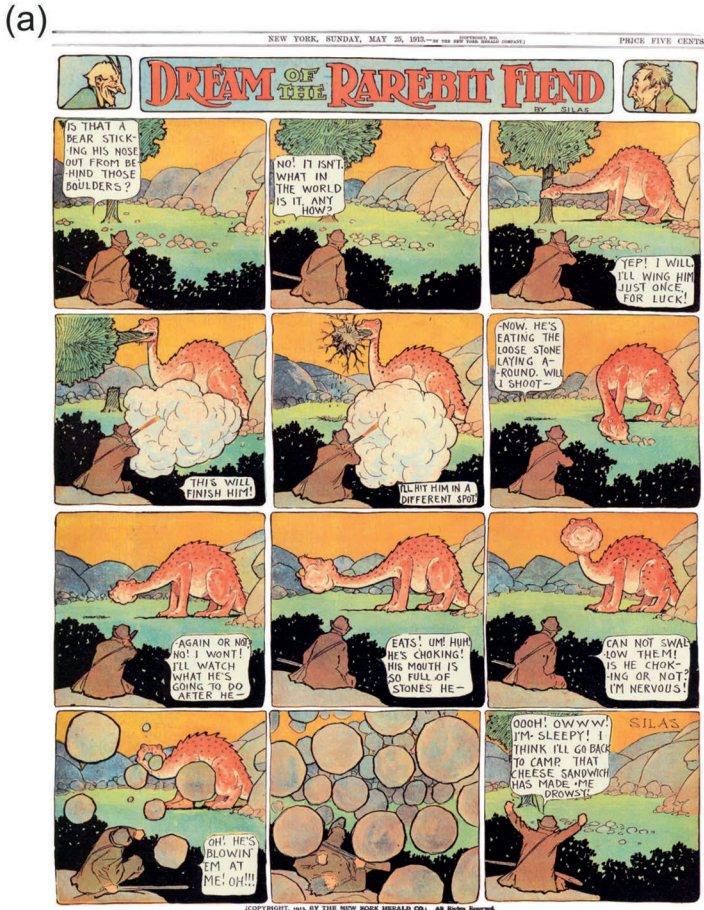
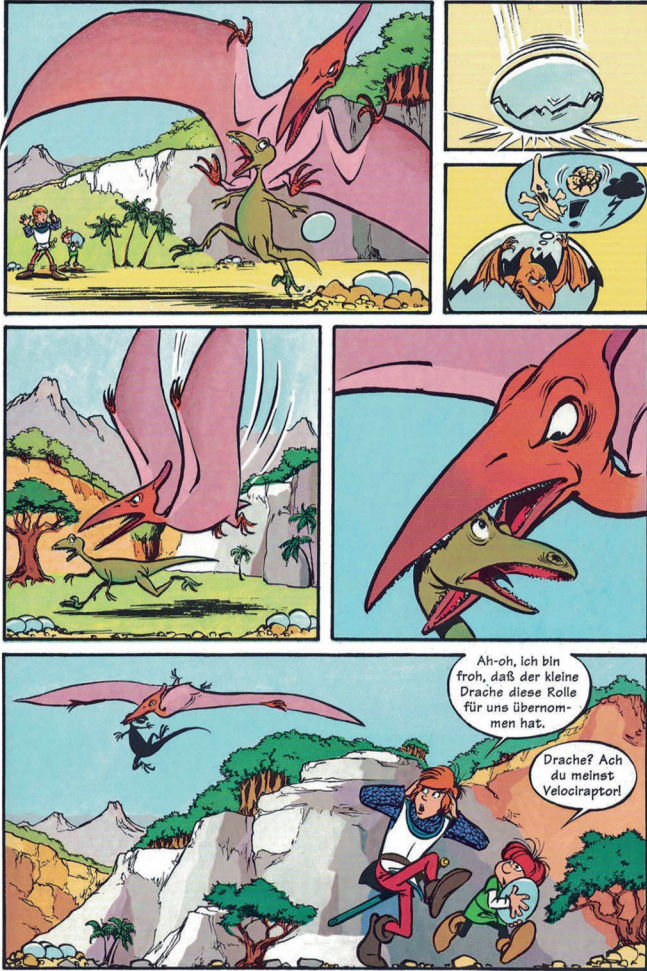
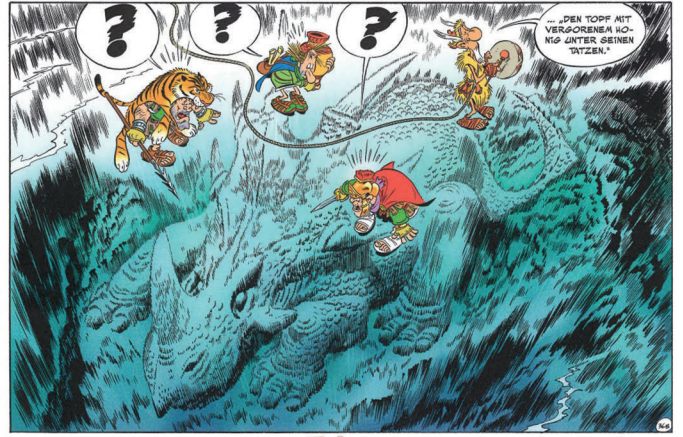



Figure 1

(a)

(b)

(c)

(d)

Figure 2

(a)

(b)

(c)

(d)

Figure 3

(a)

Figure 4

Figure 5

(a)

(b)

(c)

(d)

Figure 6

(a)

(b)

(c)

(d)

Figure 7

(a)

Figure 8

(b)

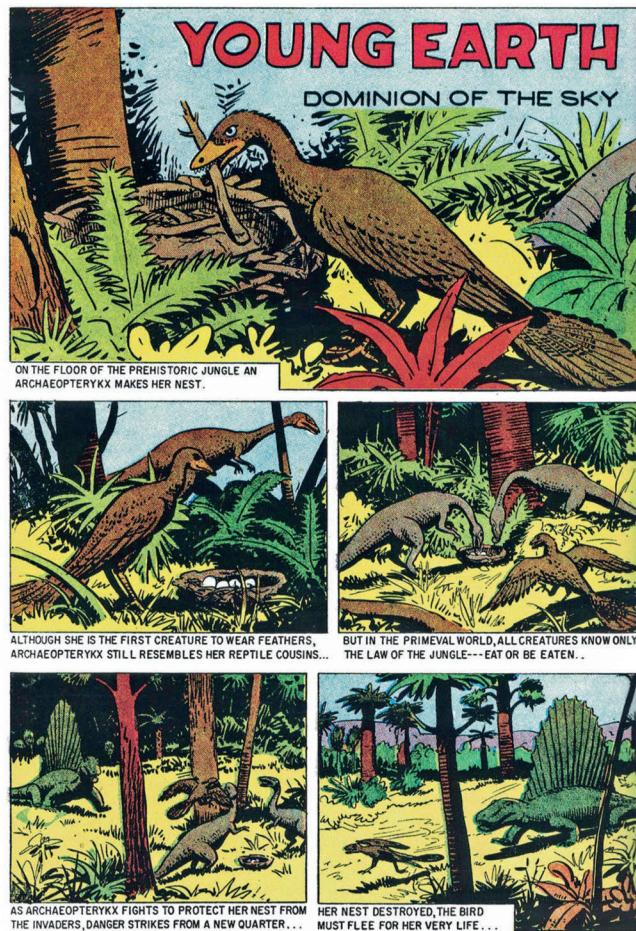
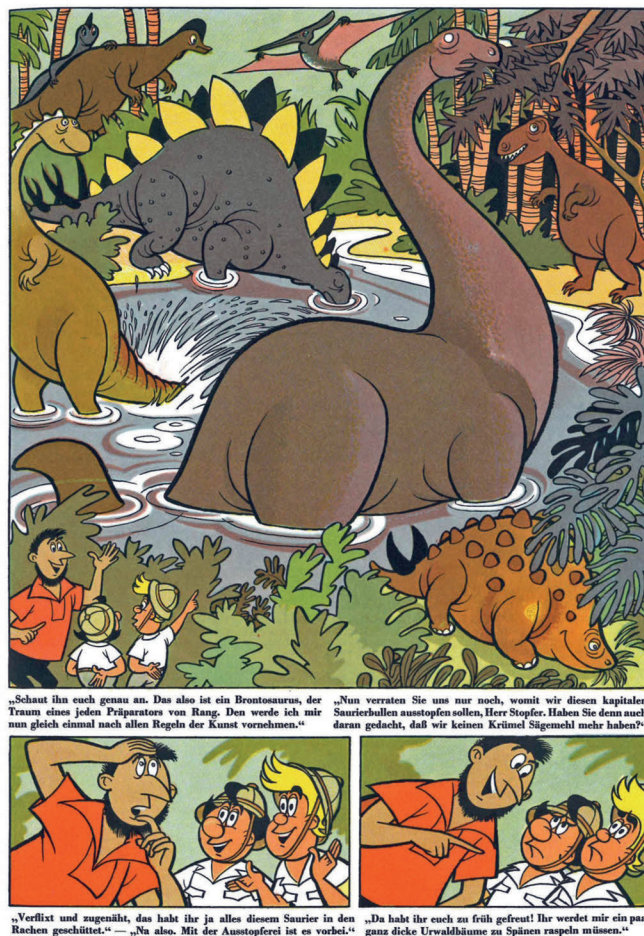
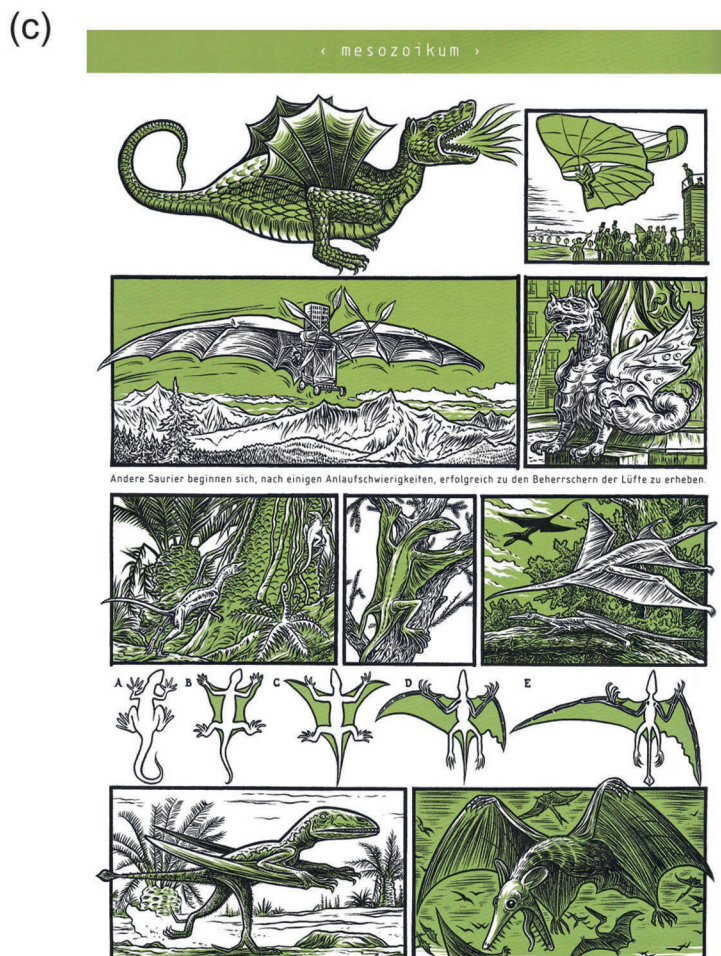
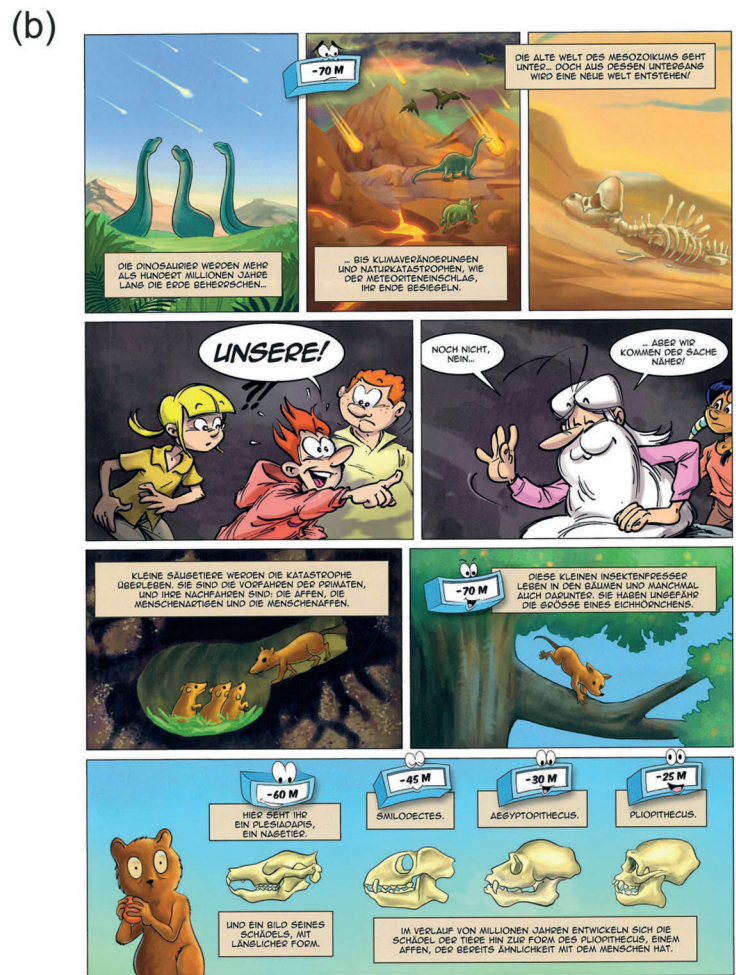
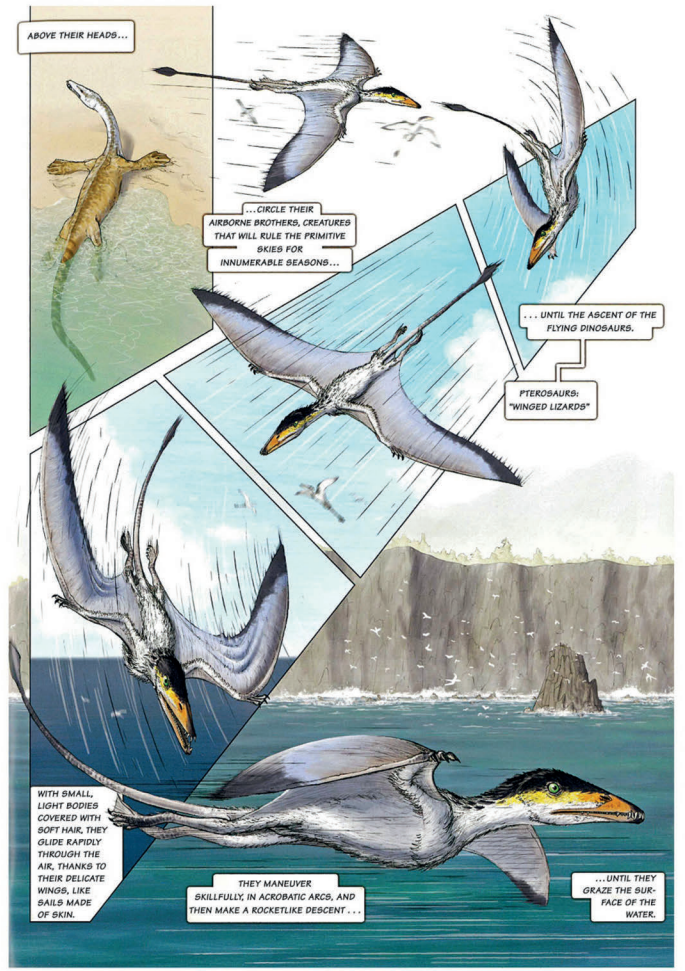
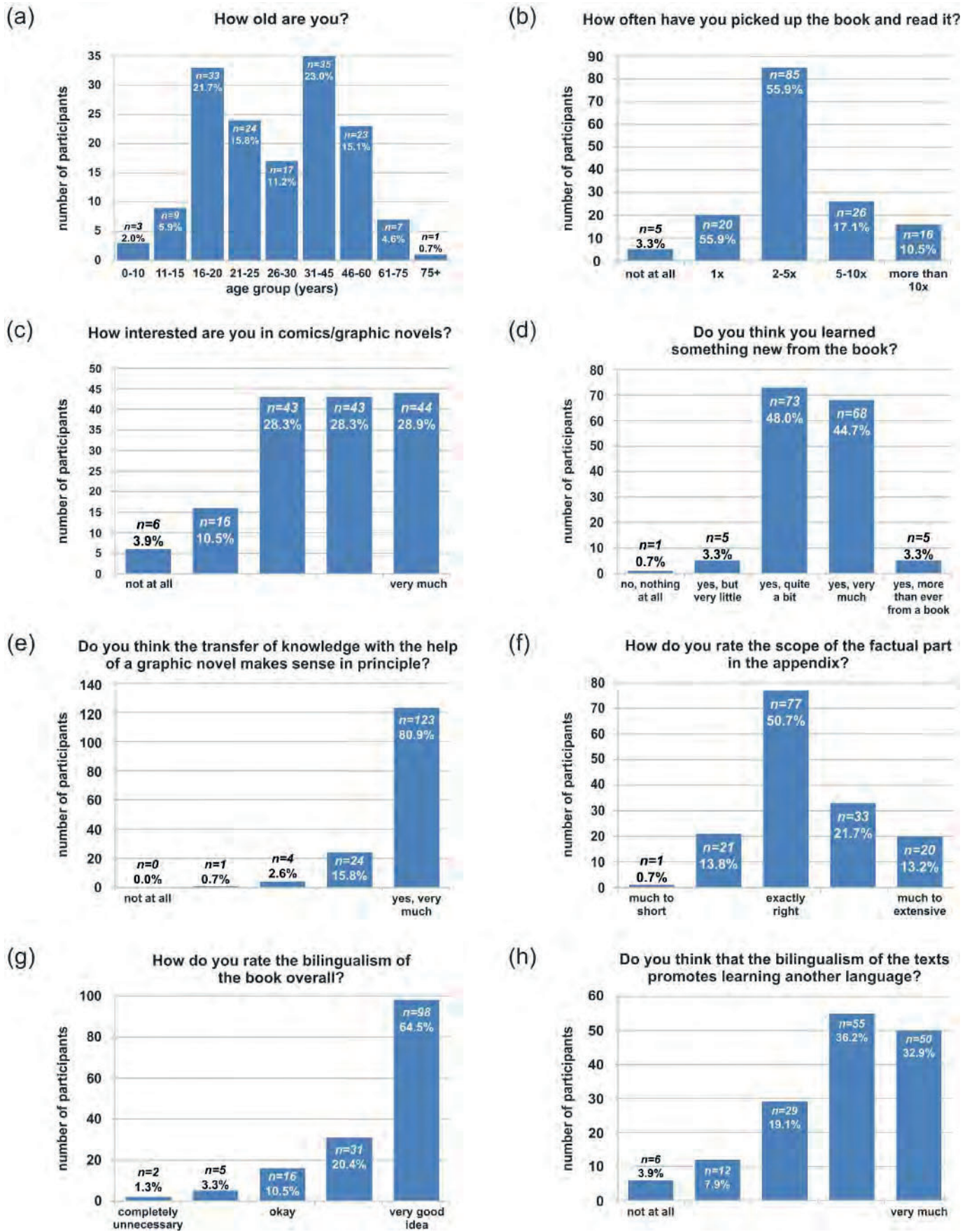
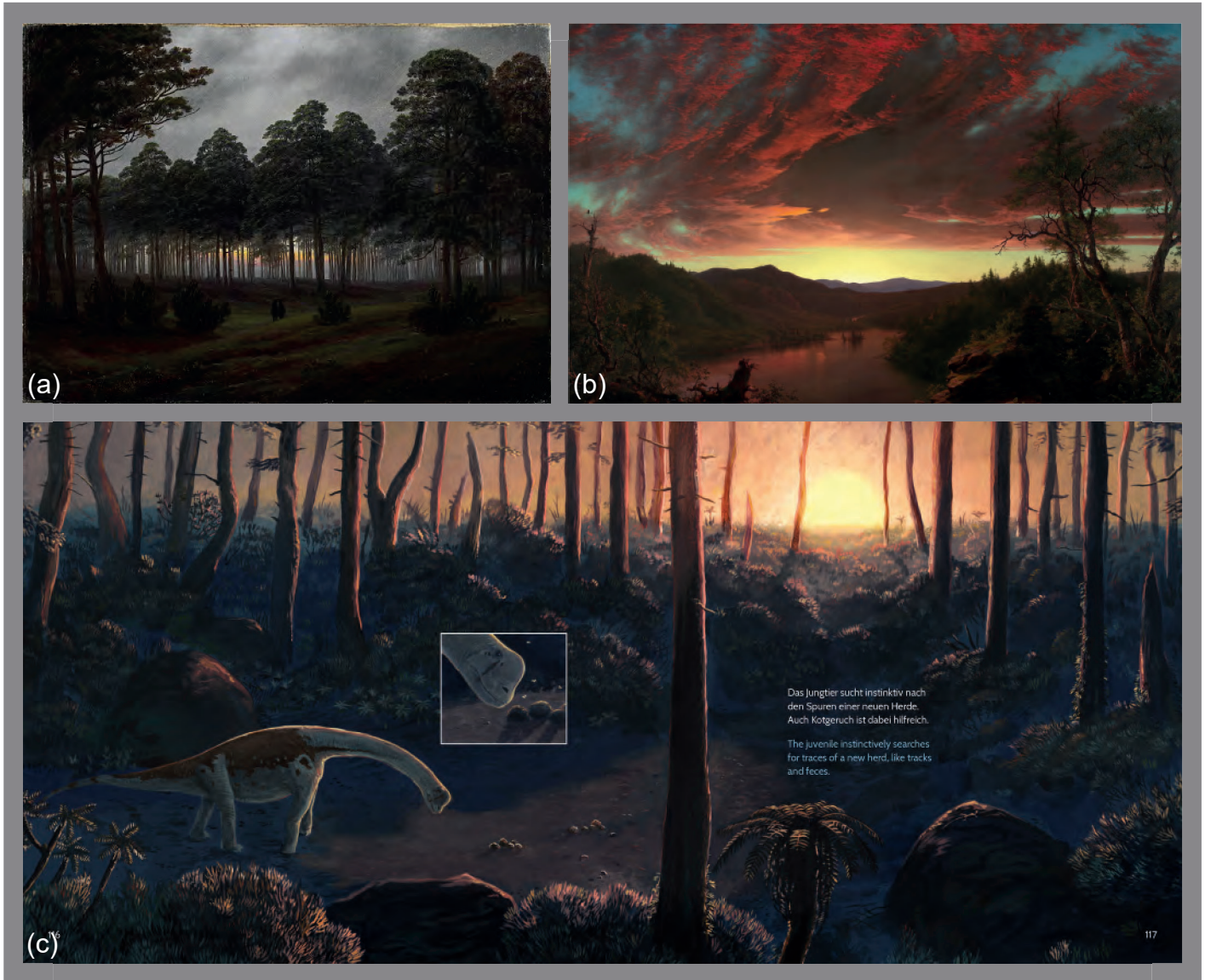
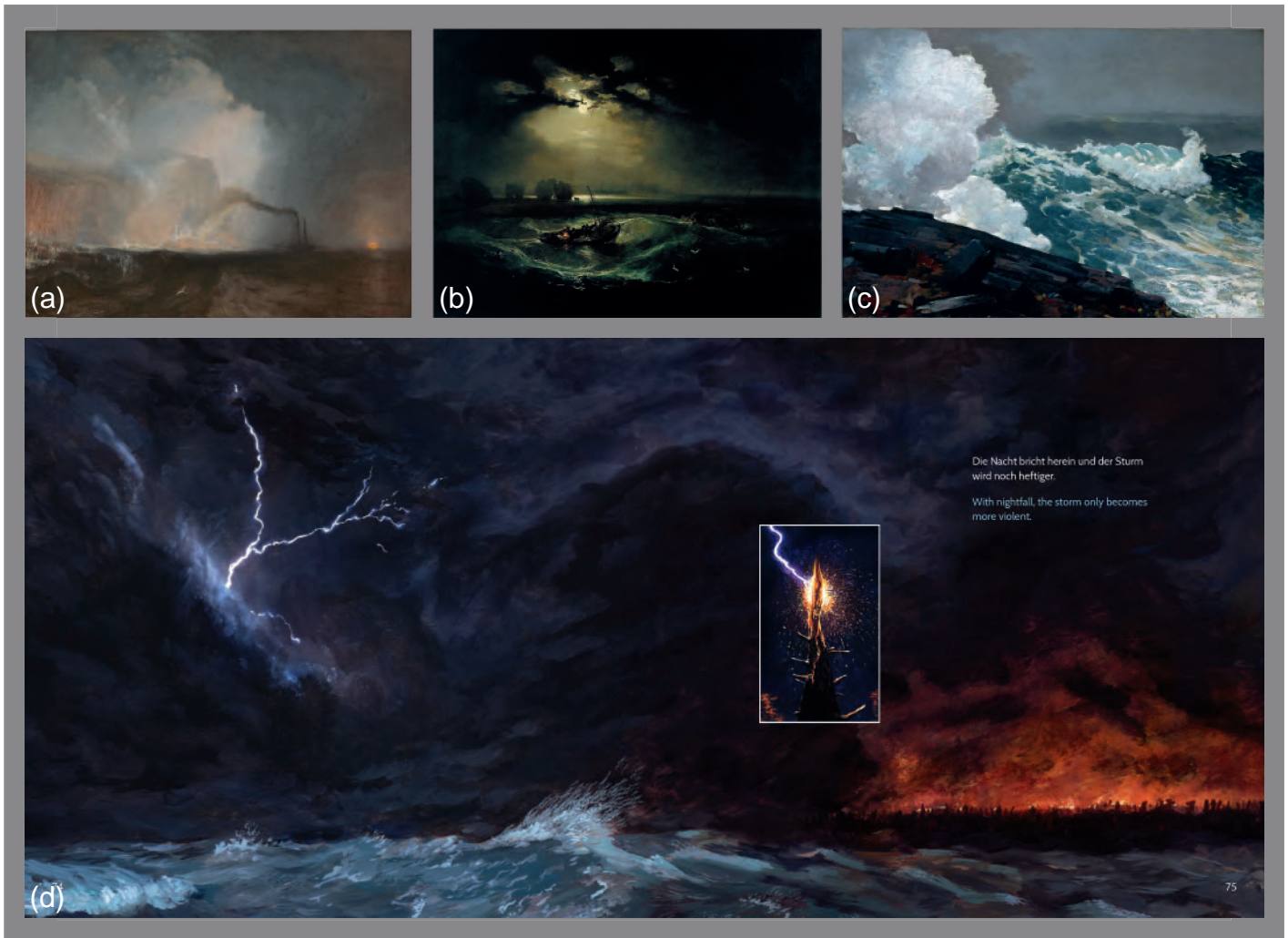



Figure 9

Figure 10

Figure 11

Figure 12

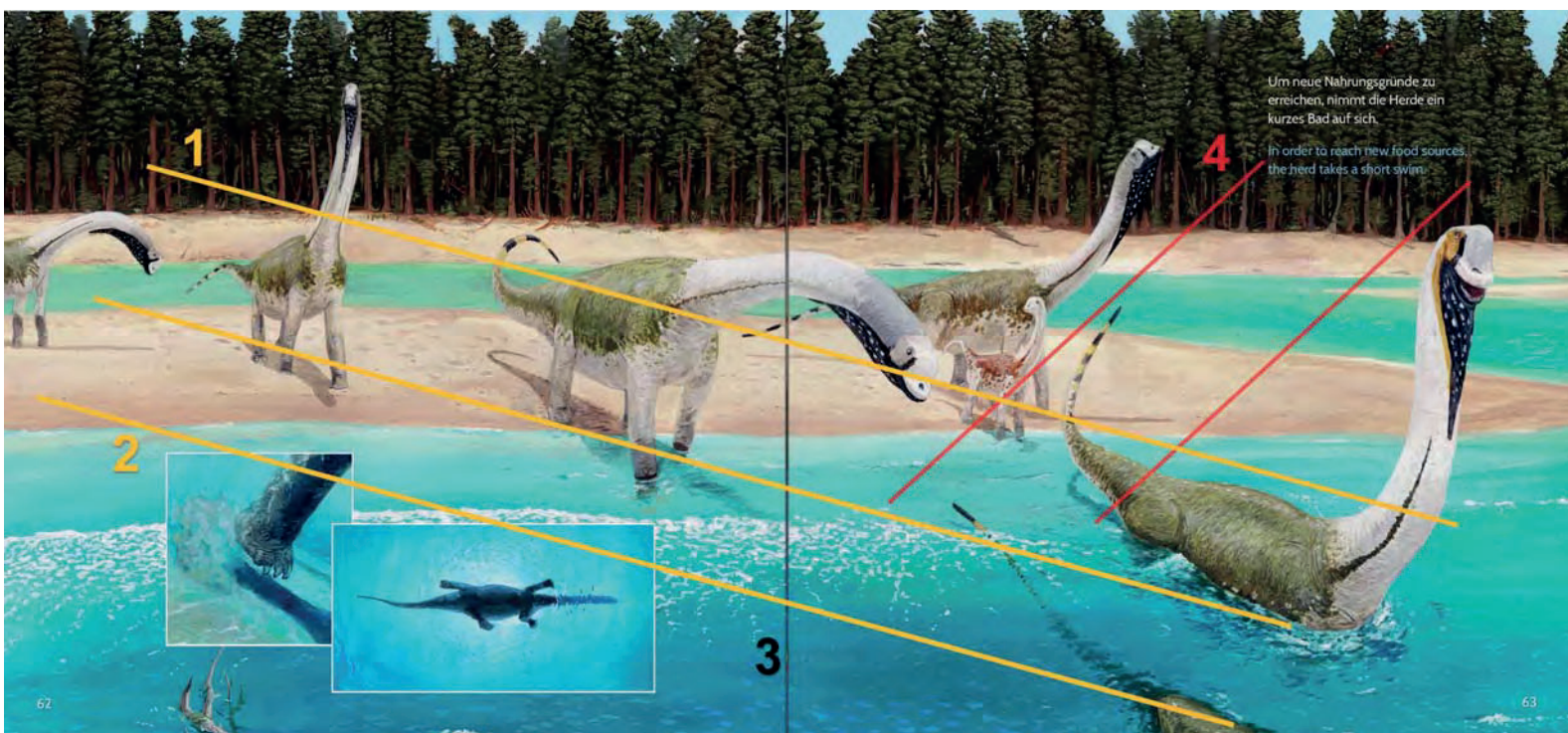
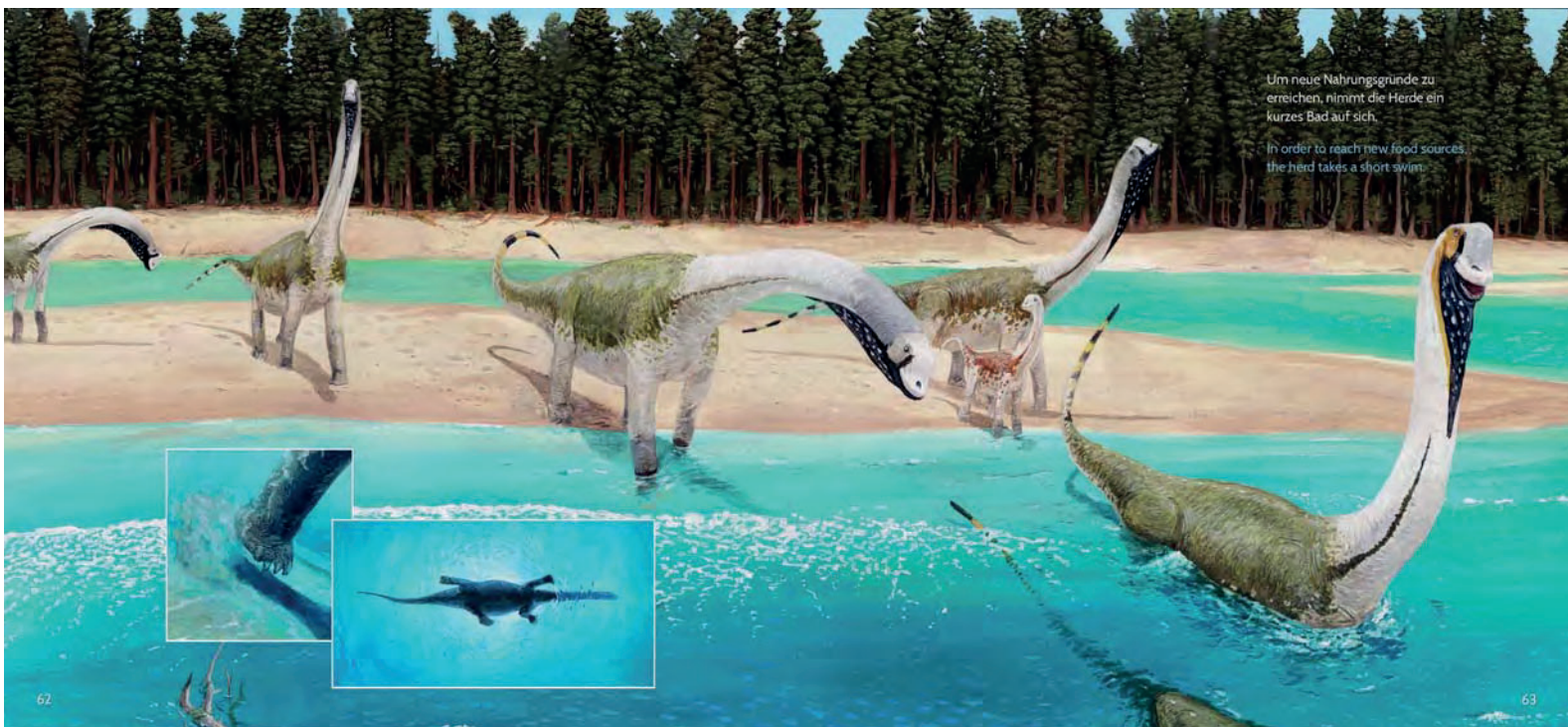



Figure 13; © Wings & Knüppe 2020

new figure 14

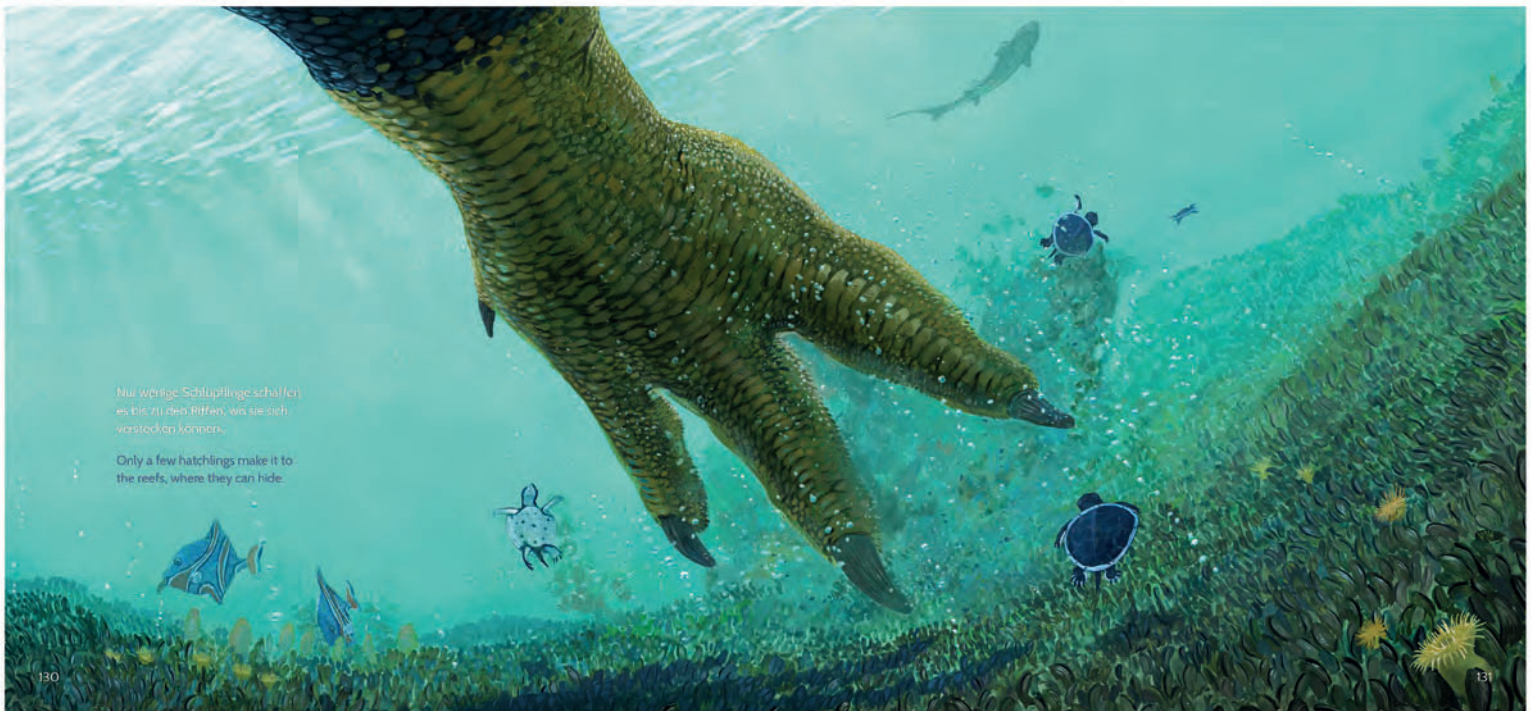
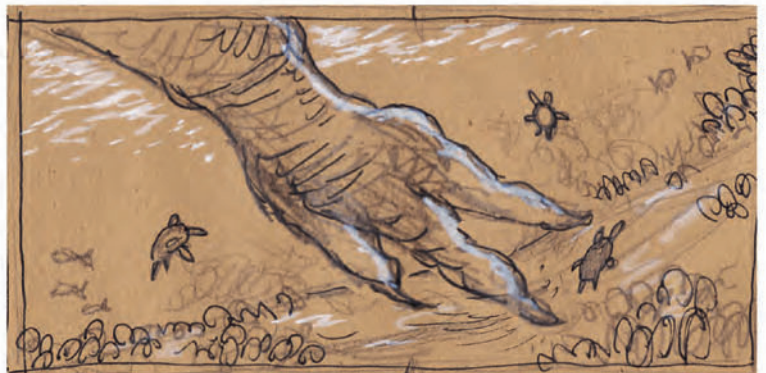
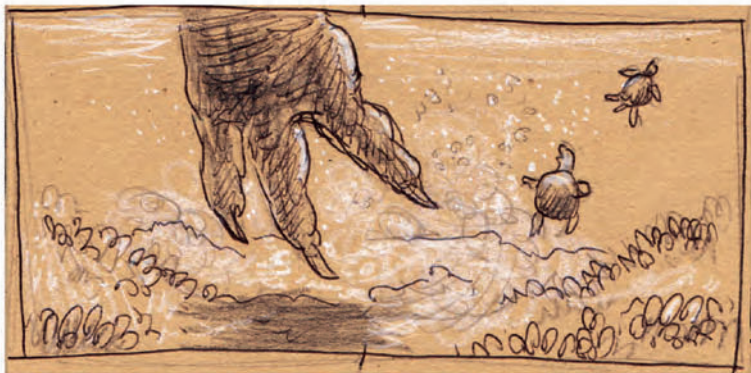
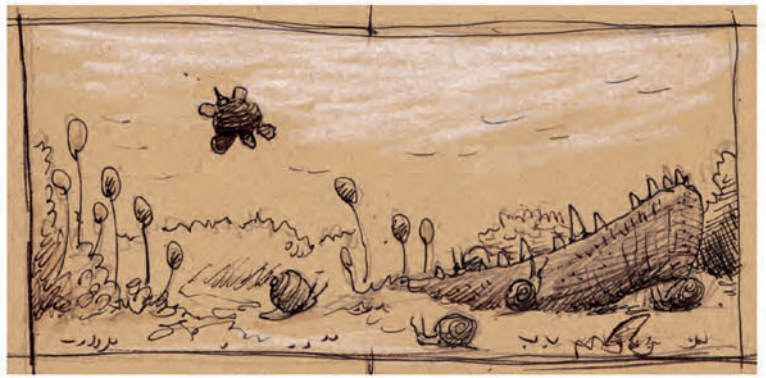



Figure XX © Wings & Knüppe 2020

new figure 15

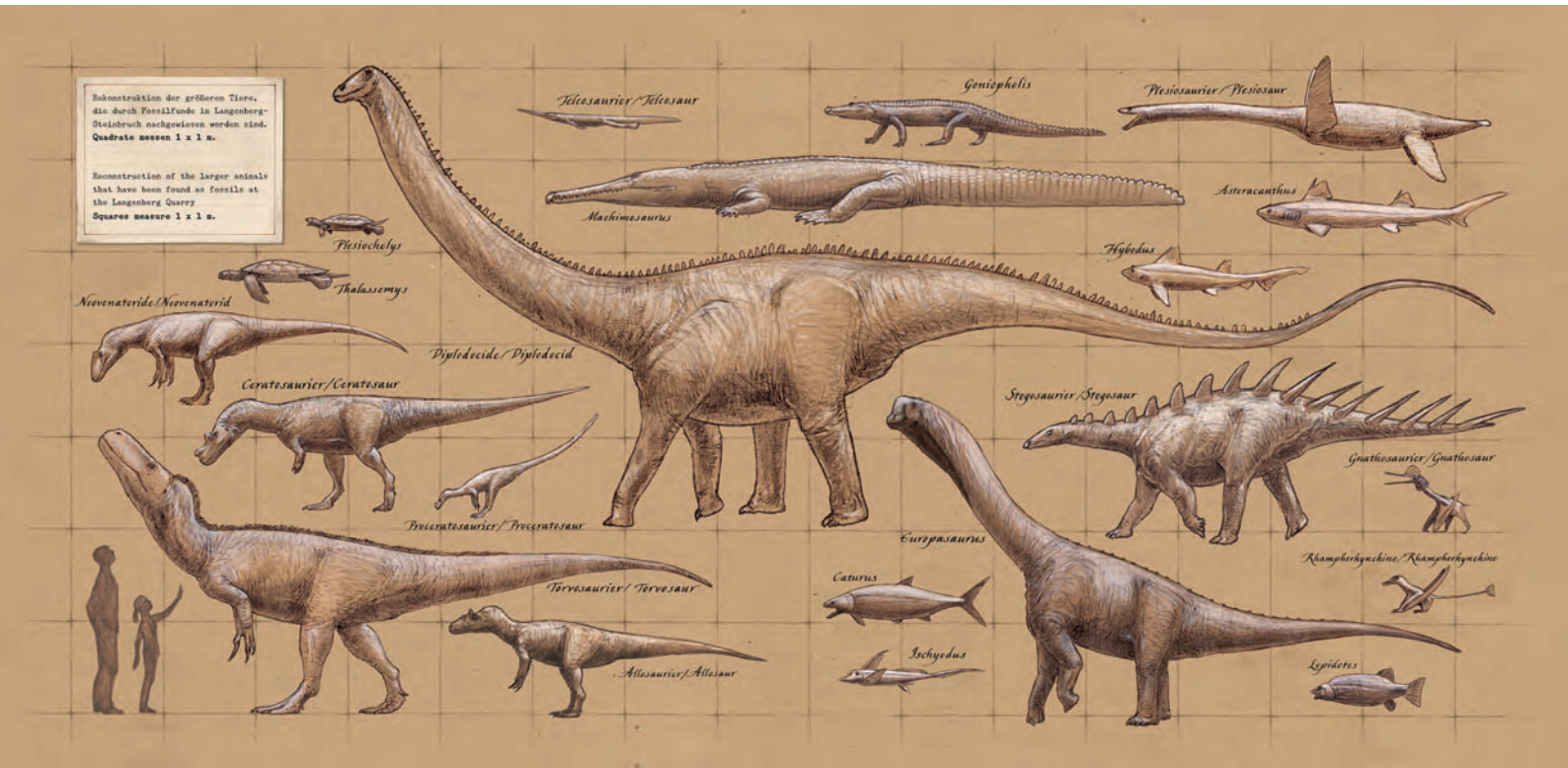



Figure 16, ; © Wings & Knüppe 2020

Figure 17; © Wings & Knüppe 2020

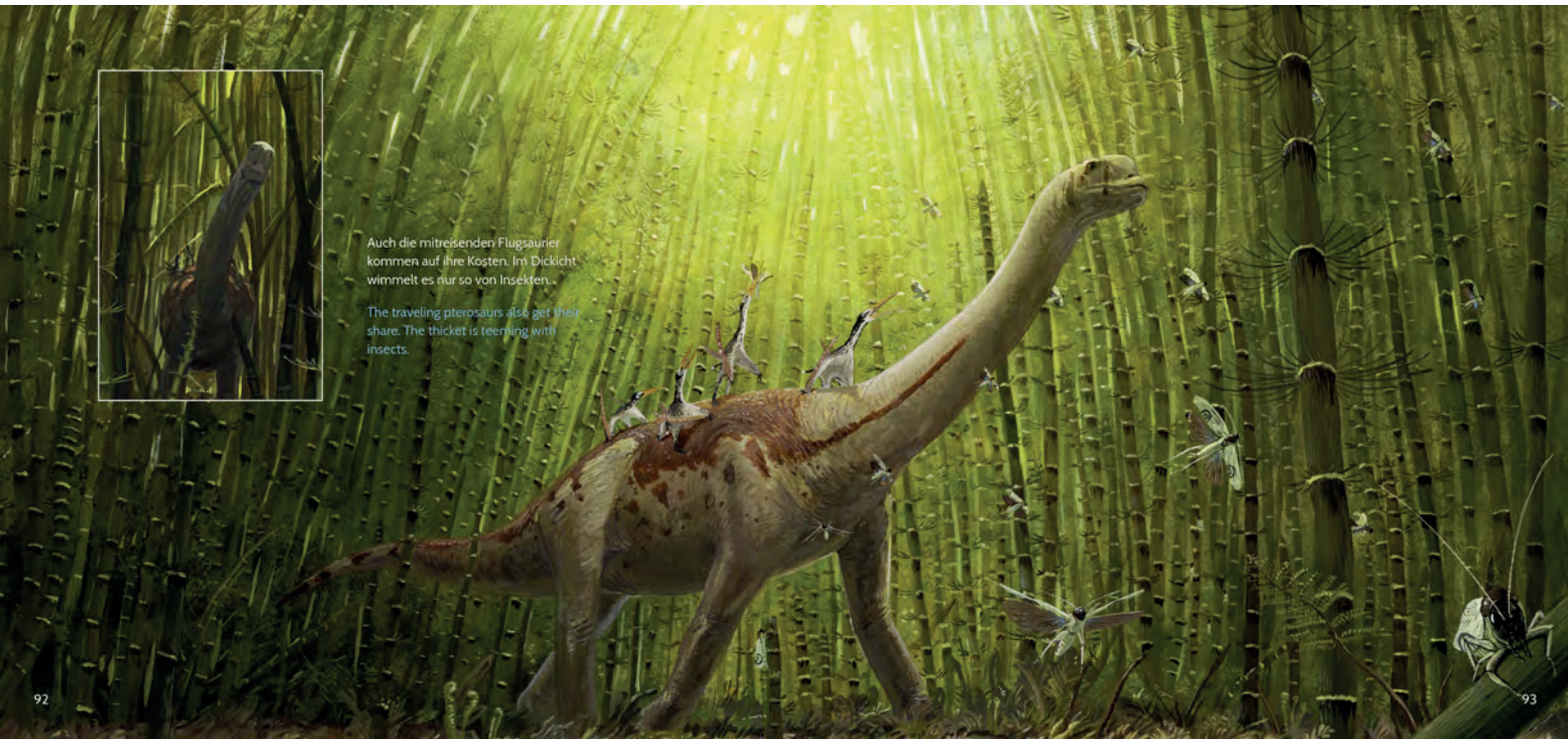



Figure 18; © Wings & Knüppe 2020