not occupying the minds of many basic scientists. The Oncode Institute aims to achieve just that. It has a substantial budget from the Dutch Cancer Society and several Dutch ministries to provide a high level of research freedom to over 60 diverse groups across the Netherlands and to facilitate their access to technologies and to each other's expertise. It is quite special that Oncode has a dedicated team that actively mines the ongoing projects for anything that may help cancer patients in the future, be it a diagnostic technology or a new therapeutic target or strategy. This nation-wide collaboration is quite unique in the world, and we hope to show years from now that it really made a difference in clinical cancer care.

Many thanks for sharing this with us, Geert. Before we say goodbye, you still need to tell us how you procrastinate. If you insist… I keep up with American politics and I obsess over American football: leftovers from two periods that I spent in the US. The first time, in San Diego, was just a few months after 9/11, and for quite some time everything Bush, Cheney, and company did was the first thing we'd talk about when going for coffee in the morning — that and either yesterday's surfing or the swell forecast for the week! Postdoc life was busy as you can tell… And I got hooked on American football! Although the Dutch football/soccer team will remain my first love, American football has become my favorite sport. It got even worse in 2014 when my family and I moved to Seattle for a sabbatical. The Seattle Seahawks (SEA-HAWKS, SEA-HAWKS!) were kicking butt, and this got my son hooked too. Now we obsess over it together, watching NFL on Sunday nights, reading every online column about it, watching highlights of retired players, checking the draft, getting up at ungodly hours to watch the Super Bowl, and so on.

But now, if you don't mind, enough interviewing. I have 'work' to do: the NFL pre-season games are about to start…

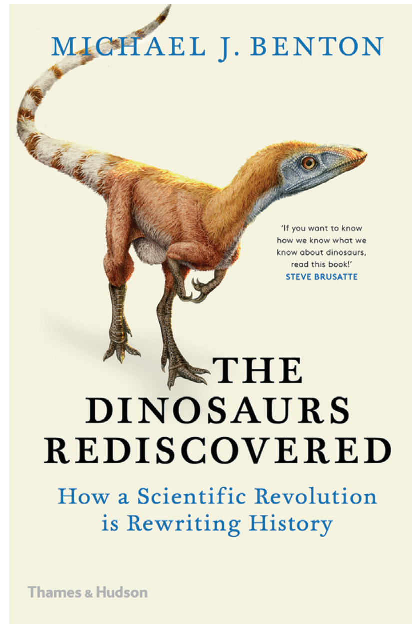
Hubrecht Institute for Developmental Biology and Stem Cell Research, Uppsalalaan 8, 3584 CT Utrecht, The Netherlands.
E-mail: g.kops@hubrecht.eu

Book review

Dinosaurs: what discoveries are truly revolutionary?

Zhonghe Zhou

Dinosaurs Rediscovered: The Scientific Revolution in Paleontology
Michael J. Benton
(Thames and Hudson, London; 2019)
ISBN: 978-0-500-05200-6



Dinosaurs have continued to fascinate generations of children and adults with their mysterious history full of truth and imagination. Their prevalence in the Mesozoic world and sudden and disastrous disappearance from the Earth by an asteroid more than 65 million years ago are elements that intrigue the public and ignite curiosity. Unlike the public, the mission of paleontologists is to discover new species and uncover new scientific information about every aspect of dinosaur evolution. Thanks to the efforts of many dinosaur experts and amateur collectors, we are lucky to have witnessed the discovery of numerous new and exciting dinosaurs, and thanks to the rapid development of technology in recent years our scientific understanding of the biology of dinosaurs has achieved so much that many would consider this progress revolutionary compared with what we knew 40 years ago.

Mike Benton's insightful and engaging new book aims to transmit this information to the public and inform the reader on what exactly paleontologists have discovered over the past 40 years with regard to scientific progress in the study of dinosaurs, a time period that constitutes a so-called scientific revolution in paleontology. The author of the book — who is a Professor of Paleontology at the University of Bristol — has a very diverse geological and paleontological background. He is also author of the famous textbook *Vertebrate Palaeontology*. He is a skillful writer and has been involved in many of the revolutionary discoveries that are described in his new book.

Dinosaurs Rediscovered is organized into nine chapters, with each one containing both stories and exciting recent discoveries and covering various topics, such as the excavation of dinosaur specimens, discoveries of the earliest dinosaurs, a discussion of their family tree, how dinosaurs breathed and behaved, what dinosaurs ate, how they moved, their ultimate extinction, and more.

As a result of his own experience and an enthusiasm and passion for dinosaurs that began in his childhood, the author's description of dinosaur excavations is both interesting and vivid. As he has accurately described, digging up dinosaurs is one of the best experiences for a paleontologist. The field methods have changed little over the past 150 years — nothing beats a good pair of eyes and strong shoulders!

It is the dream of any paleontologist to discover the ancestor of a group and reveal the ancestral condition that gave rise to a diversity of species. The discovery of *Asilisaurus* is undoubtedly one such fossil, pushing back the origin of dinosaurs from 230 million to 245 million years ago. The author has also discussed the earliest radiation of dinosaurs in both a paleogeographic and paleoenvironmental context. I particularly appreciate the author's comment that, "in evolution, organisms mostly avoid competition by shifting their ecological niches — they chose a different diet or geographic range".

Since the time of Darwin, we have realized that all biological species are related to each other. Reconstructing the evolutionary tree or phylogeny of dinosaurs has always been a central topic of debate for 'dinosaurists'. The author has shared his perspective of the cladistics revolution and how it has been gradually applied to the study of the dinosaur family tree and how mathematics and computational technology has helped in the search for the supertree that is nearest to the truth.

Over the past 40 years, alongside the remarkable dinosaur discoveries made worldwide, significant progress has been made in our understanding of the biology and physiology of dinosaurs that owes a great deal to the use of new technologies, such as high-resolution CT scanners, scanning electron microscopes (SEM), transmission electron microscopes (TEM), synchrotron X-ray imaging, and so on. As the author states, we have learned more in the past ten years about thermoregulation, color, and behavior than in the preceding 100 years combined.

Paleontologists have now generally accepted the hypothesis first proposed by Thomas Huxley in 1868 that birds originated from dinosaurs, and they have uncovered numerous details concerning the transition from dinosaurs to birds. Modern birds are warm blooded and have an efficient respiratory system. How did dinosaurs breathe? They probably breathed air through their lungs unidirectionally and had high metabolic rates similar to — although not exactly the same as — modern birds. With the discovery of many small-sized dinosaurs particularly from the Jurassic and Early Cretaceous of China, the existence of many bird-like arboreal (tree-dwelling) dinosaurs has become well known. As the author correctly states, "evidence of the Chinese fossils is hugely in support of the traditional 'tree-down' model for the origin of flight". The latest discoveries of membranous-winged dinosaurs demonstrate that feathered wings are not the only path to become volant during the dinosaur–bird transition [1]. Meanwhile, with the assistance of new engineering techniques, paleontologists are now able to tell how dinosaurs actually moved and ran. The author has provided a thorough historical account of how paleontologists have strived to reconstruct dinosaur locomotion using the principles of biomechanics. A recent *Nature* article even reported on a study of locomotion that used a robot to simulate the movement of a 290-million-year-old tetrapod [2].

How did dinosaurs grow? Why and how did some sauropods become so large? All such questions are popular among the general public. Paleontologists have made significant advances toward a better scientific understanding of the life history of dinosaurs. Many of the secrets are hidden in the bones, and paleontologists are now more comfortable with techniques that minimize damage as much as possible to conduct histological analysis that provides important data regarding growth and metabolic rates.

How and what did dinosaurs eat? This seems like the kind of question often asked by kids, yet this is important information for reconstructing paleoecosystems. The author has focused on how paleontologists have used engineering software, such as FEA (finite element analysis), to shed light on the feeding function of dinosaurs. However, it is also notable that many discoveries of dinosaurs and early birds have provided direct evidence of their feeding behavior and trophic habits [3] to the extent that there is no question as to the diet of certain taxa.

Thanks to the identification of preserved melanosomes in the fossil feathers of dinosaurs, we can now at least partially reconstruct the color of some extinct animals rather than rely on speculation. The discovery of diverse types of feathers as well as their color in feathered dinosaurs and early birds has also brought up one of the important issues in evolution, sexual selection, which has probably played a more important role in the evolution of birds and feathers than previously thought. The recent discovery of fossilized ovarian follicles as well as the discovery of medullary bone in some early birds provide direct evidence of female gender in these fossils. It is also notable that some other pioneering work on the evolution of the beta-keratin in dinosaurian feathers has not only provided an independent way of distinguishing the melanosomes from microbes but has also opened a window into investigating the molecular evolution of extinct organisms in deep time [4]. It is probably fair to say that the potential preservation of soft tissues and biological molecules in ancient animals from deep time is far from appropriately appreciated by paleontologists [5]. We must remember that absence of evidence is *not* evidence of absence.

Life reconstruction of *Ambopteryx longibrachium*: A recently discovered Jurassic membranous-winged dinosaur from China [1]. Illustrated by Mr. Chung-Tat Cheung.

The end-Cretaceous mass extinction (about 65 million years ago) of non-avian dinosaurs is introduced in the last chapter. I am surprised that the author — as a geologist — focused so much on the impact theory, i.e., that an asteroid striking the Earth caused the extinction of all dinosaurs. This simple scenario is always preferred by the public and somehow exaggerated by the entertainment industry. However, in the past 500 million years there were at least five major extinction events. The end-Permian extinction (about 250 million years ago) is ranked as the largest extinction event, causing the disappearance of over 90% percent of marine species. New geochronological studies have correlated large volcanic activity (or a large igneous province) more precisely with this mass extinction. Similar conclusions have been made by geologists regarding the end-Triassic (about 200 million years ago) and the end-Cretaceous extinctions [6]. As to the cause of non-avian dinosaur extinctions, it is probably fair to conclude — as noted by the author — that "we cannot yet fully integrate the devastation caused by the asteroid strike with that caused by the longer-running Deccan Trap eruptions in India".

Although generally I enjoyed the book, I cannot agree that paleontology has become a true science only in the past 40 years. This period marks the discovery of many exceptionally preserved new dinosaur species that constitute the basis for changing our understanding of dinosaur biology. Discovery of a fact or truth about nature is itself part of the science and often constitutes the most fascinating aspect to the public. No one would doubt the significance of discovering the Higgs boson in physics. Paleontologists should not be bothered by being called 'stamp collectors', a term that is itself unfairly used for many scientific disciplines that are often dealing with complex natural phenomenon and rely on endless observations and the collection of important samples. The current trend in the study of paleontology is almost certainly characterized by an integration of biological and geological progress and the application of new technologies that produce revolutionary ideas about dinosaur biology, yet nothing would be as exciting to both paleontologists and the public alike as the revolutionary discoveries themselves.

REFERENCES

1. Wang, M., O'Connor, J.K., Xu, X., and Zhou, Z. (2019). A new Jurassic scansoriopterygid and the loss of membranous wings in theropod dinosaurs. Nature *569*, 256–259.
2. Nyakatura, J.A., Melo, K., Horvat, T., Karakasiliotis, K., Allen, V.R., Andikfar, A., Andrada, E., Arnold, P., Lauströer, J., Hutchinson, J.R., *et al.* (2019). Reverse-engineering the locomotion of a stem amniote. Nature *565*, 351–355.
3. O'Connor, J.K. (2019). The trophic habits of early birds. Palaeogeogr. Palaeocl. *513*, 178–195.
4. Pan, Y., Zheng, W., Sawyer, R.H., Pennington, M.W., Zheng, X., Wang, X., Wang, M., Hu, L., O'Connor, J., Zhao, T., *et al.* (2019). The molecular evolution of feathers with direct evidence from fossils. Proc. Natl. Acad. Sci. USA *116*, 3018–3023.
5. Lindgren, J., Sjövall, P., Thiel, V., Zheng, W., Ito, S., Wakamatsu, K., Hauff, R., Kear, B.P., Engdahl, A., Alwmark, C., *et al.* (2018). Soft-tissue evidence for homeothermy and crypsis in a Jurassic ichthyosaur. Nature *564*, 359–365.
6. Schoene, B., Eddy, M.P., Samperton, K.M., Keller, C.B., Keller, G., Adatte, T., and Khadri, S.F.R. (2019). U-Pb constraints on pulsed eruption of the Deccan Traps across the end-Cretaceous mass extinction. Science *363*, 862–866.

Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, P.O. Box 643, Beijing 100044, China.
E-mail: zhouzhonghe@ivpp.ac.cn

Quick guide

Cuckoo catfish

Martin Reichard

Why 'cuckoo' catfish? The 'cuckoo' part of the name references the cuckoo bird. Like their bird counterparts, cuckoo catfish smuggle their eggs into the care of foster parents. This reproductive strategy of relinquishing parental duties to foster parents — known as brood parasitism — has evolved on several independent occasions in unrelated animal groups. In a few species, it has developed to the point that parents can no longer raise their own offspring — termed obligatory brood parasitism.

Why are cuckoo catfish special? Among vertebrates, only a few bird lineages have evolved obligatory brood parasitism. Social insect (ants, bees, wasps and also some beetles) are invertebrate examples. Uniquely among brood parasites, the cuckoo catfish (*Synodontis multipunctatus*) has evolved brood parasitism even though its relatives show no parental care. The cuckoo catfish is a member of a small group of squeaker catfishes (family Mochokidae) from Lake Tanganyika, with approximately ten locally endemic species. With the exception of the cuckoo catfish, all other squeaker catfish species (in Lake Tanganyika and elsewhere) reproduce by scattering their eggs during mating and provide no care to their young.

Who is parasitized? The cuckoo catfish exploits the parental care of mouthbrooding cichlids. Haplochromine cichlids have undergone spectacular species radiations in the African Great Lakes (Tanganyika, Malawi and Victoria), and this diversification is thought to have been facilitated by their strong parental habits. These cichlids lay their eggs in a specially prepared nest, and female mouthbrooders collect their eggs immediately after spawning to incubate them in their mouths for a period of about three weeks.

How do cuckoo catfish fool cichlids? Cuckoo catfish invade cichlid nests during spawning where they quickly deposit their own eggs which then are mistakenly collected by the female cichlid. Observations in captivity show that groups of cuckoo catfish can overwhelm spawning pairs of cichlids, disrupting spawning and attempting to eat the cichlid's eggs. Male cichlids respond aggressively to intruding catfish, but repeated intrusions by groups of cuckoo catfish eventually enable them to spawn with the cichlids. The catfish release batches of about 10 eggs at a time. When catfish eggs are released, female cichlids may inadvertently collect some of them in their mouths as they quickly try to pick up their own eggs, which are at risk of being eaten by intruding catfish.

Why don't cichlids avoid catfish eggs? Catfish chicanery does not include egg visual mimicry. Catfish eggs are markedly different in shape and are smaller than the eggs of their hosts (Figure 1). Recent experiments suggest that cichlid hosts that coexist with cuckoo catfish in Lake Tanganyika may be able to selectively reject cuckoo catfish eggs, but how host females discriminate cuckoo catfish eggs is still unknown. Strikingly, mouthbrooders from other African lakes seem helpless once infected with catfish eggs. So far, too few host species have been studied to see whether this is a general pattern, but it seems that — as in cuckoos and their host birds— a coevolutionary 'arms race' operates between cuckoo catfish and Lake Tanganyika cichlids, while catfish are one evolutionary step ahead of cichlids from all other locations.

What is the fate of the host brood? Having a cuckoo catfish as a step-sibling is fatal for baby cichlids. Catfish eggs hatch earlier than those of cichlids. However, unlike avian cuckoo chicks, which often evict host offspring from the nest, baby cuckoo catfish devour the host embryos, one by one, over several days (Figure 1). Cichlid embryos have a large yolk sac, a nutrient-rich energy supply to sustain their long incubation in

