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Patterns in Palaeontology: How the thunder lizard lost its name

by Chloe Marquart*[1]

When I tell the average stranger that I'm a palaeontologist, the first question that I'm inevitably asked is: "Like Ross from Friends?" The second is: "Have you named any dinosaurs?"

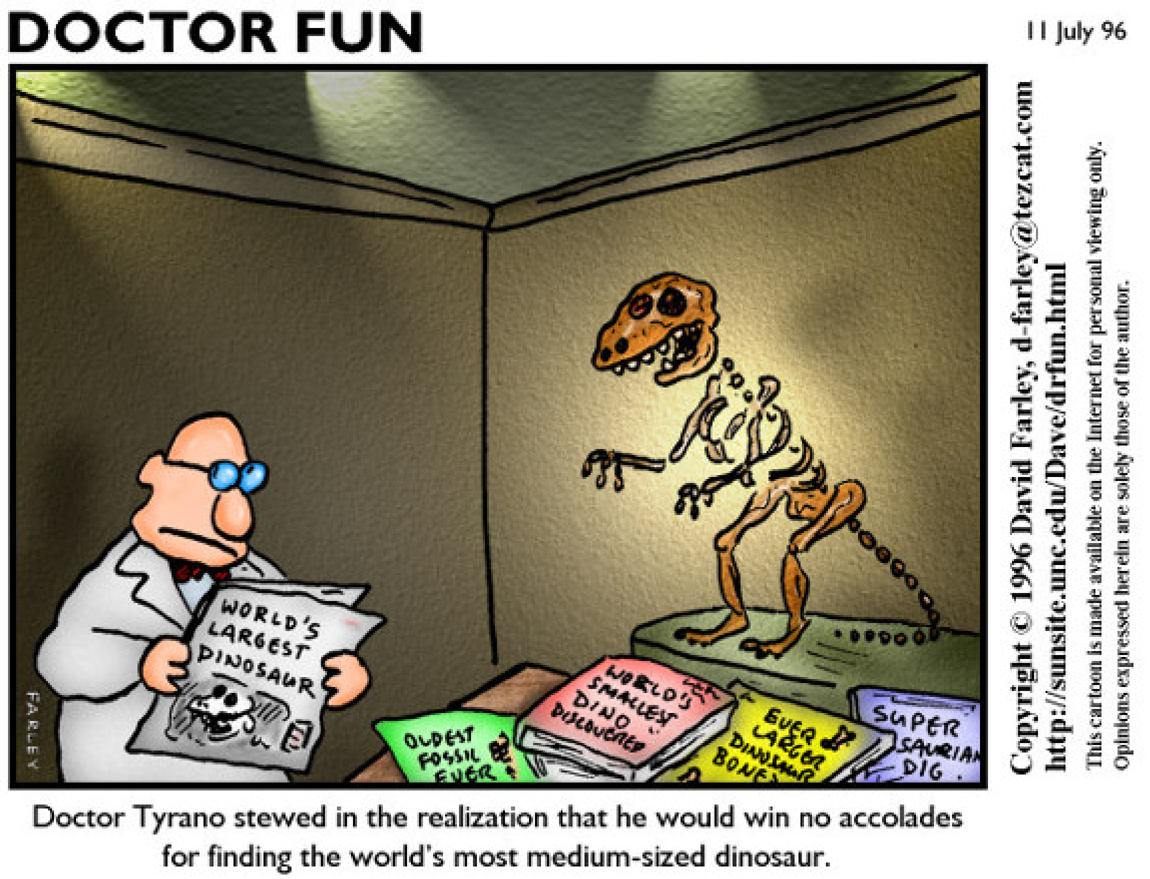

FIGURE 1 — SOURCE.

The naming of fossils is actually a very small part of the work that palaeontologists do, but it often garners the most attention from the press and public. It can be difficult for people to understand how scientists can suddenly decide that a well-known, often iconic name has never 'existed' – in a scientific sense, at least. Many grown adults still mourn the loss of their beloved *Brontosaurus* (more on him later), and in the past few years, campaigns were begun to 'Save*Triceratops*' when it was declared that this dinosaur and *Torosaurus* might be the same animal (Fig. 2). Although designating a new species might seem to guarantee a little piece of immortality for its discoverer, the names of animals are not set in stone and may be changed by anyone who can make a case for it.

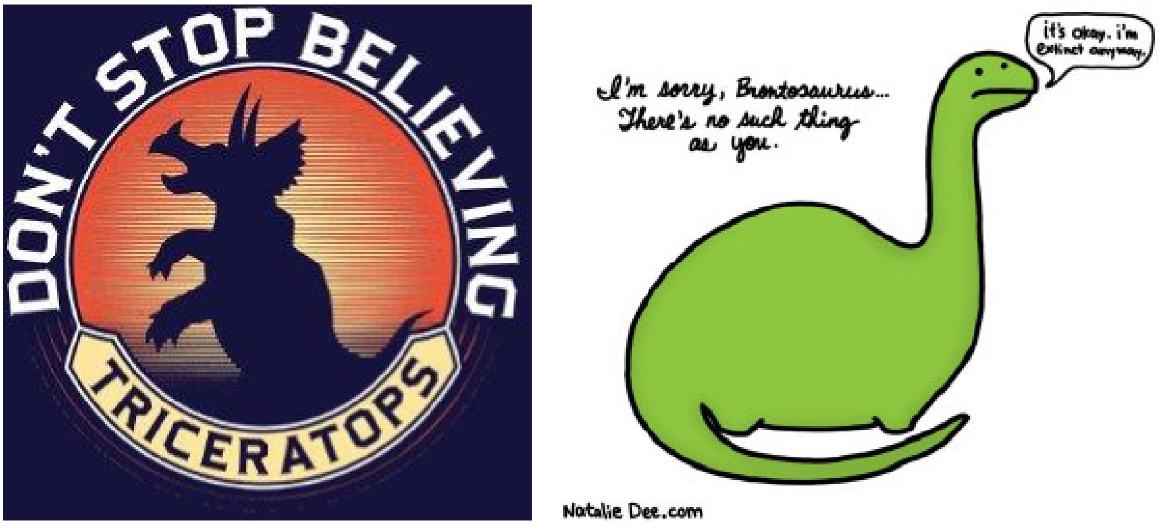

FIGURE 2 — PUBLIC SUPPORT REMAINS STRONG FOR DISPUTED SPECIES (ALTHOUGH IT IS ACTUALLY THE EXISTENCE OF TOROSAURUS, NOT TRICERATOPS, THAT IS DEBATED). SOURCE 1. SOURCE 2.

Naming names

The use of formal, two-part Latin names for living things was introduced by Swedish naturalist Carl von Linné (Linnaeus) in 1758. Previous attempts had been made to create a standardized system, but Linnaeus's idea was elegant and simple, allowing the relatedness of different organisms to be indicated by their unique names. Each organism is given a genus and then species name; at first, these were in Latin or Greek, but today combinations of all linguistic stripes (except English) are used. The names are often shortened for convenience, so for example *Tyrannosaurus rex* becomes *T. rex*, and they are always written in italics. Animals that share the same genus name are closely related (Fig. 3). Those that share neither species nor genus name are less similar, but may be grouped together in broader categories such as 'families' (for example the Felidae — cats).

There are many rules about the naming of species, all laid down by the International Commission on Zoological Nomenclature. One basic law is that you cannot name a species after yourself, although you can style one after someone else. Usually these will be scientists, but, for example, both writer Michael Crichton (author of *Jurassic Park*) and musician Mark Knopfler have dinosaurs named after them. Additionally, the names must not be too silly, although many scientists get around this rule by justifying their selection on apparently sensible grounds: a notable example is the Chinese trilobite *Han solo*, officially named after the Han people. Names must be published in a recognized, peer-reviewed journal — those included in dissertations or self-published works are not valid — and must not be 'preoccupied', or already in use for other species.

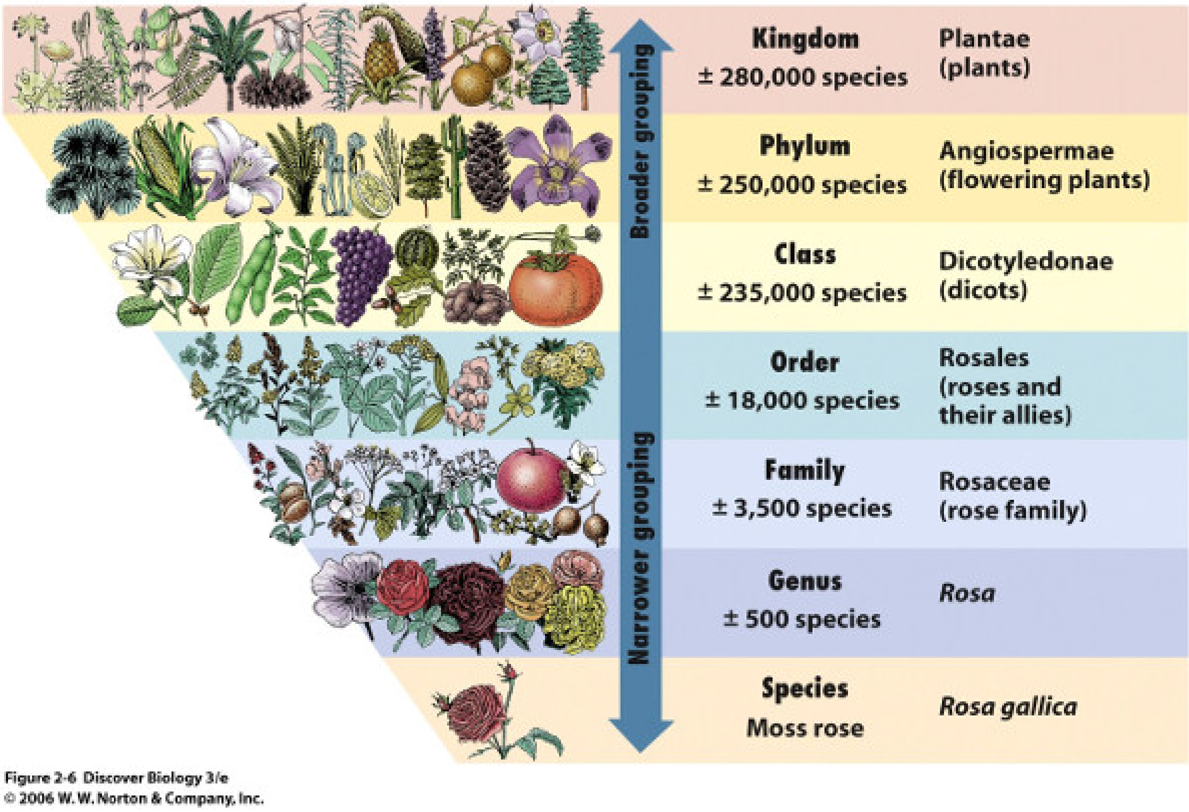

Figure 3 — The hierarchy of taxonomic divisions, ranging from kingdom to species. Only the genus and species names are italicized.

Source: Discover Biology (Norton), via Sacramento State.

Most importantly, for a species to be considered valid, there must be a designated reference specimen that other material can be compared to: one individual that is considered typical of the group and is known as the holotype. In palaeontology, the holotype is often a newly excavated specimen and may be the only known example of that species. With living animals, it is more common that several individuals will be known (perhaps discovered together in an isolated area). These specimens, if mentioned explicitly in the description, are collectively known as the type series. The individual that best exhibits the traits used to describe the species is the holotype and the others are known as paratypes.

Just what is a species?

Before a species can be named, a definition of a species must be agreed. More than 20 'species concepts' have been proposed over the years and all have major strengths and weaknesses, philosophically and practically. These days, most scientists use the biological species concept: if two animals can breed together and produce fertile offspring, then they are the same. Thus, although very different in appearance, all dogs belong to the same species (*Canis lupus familiaris*) — even if a Great Dane would be unlikely to mate with a Chihuahua, making the two populations 'reproductively isolated' (Fig. 4). In time, this isolation is expected to lead to genetic divergence, so that if their descendants tried to mate after many, many generations, there would be no offspring, or no fertile ones.

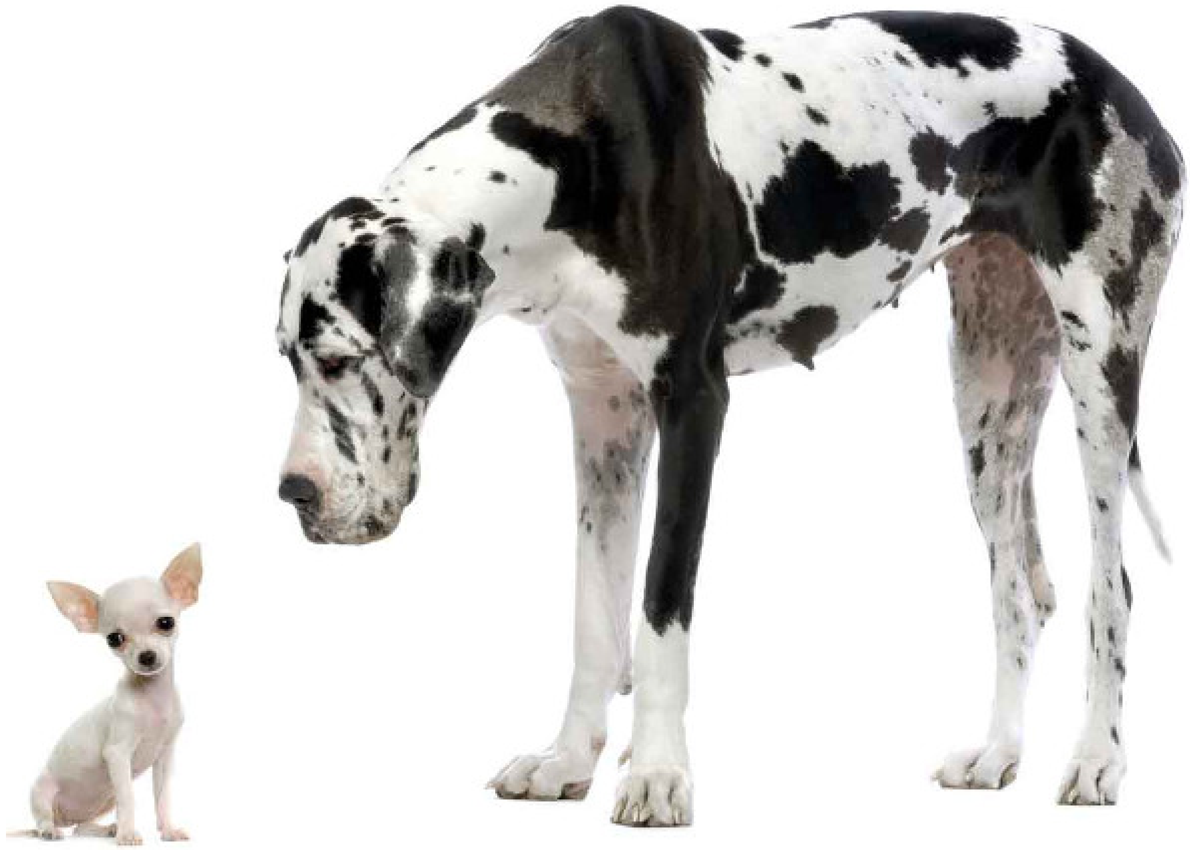

FIGURE 4 — THERE'S NOTHING GOING ON HERE. HONEST. SOURCE.

However, things are rarely as clear-cut in nature, and this definition has many limitations. For example, it relies on the assumption that species only reproduce sexually, which is not true of many organisms, including some plants and bacteria and even some insects, fish and reptiles. Also, many species known to be distinct at the genetic level can produce fertile hybrid offspring, which could be considered species. Most commonly this occurs with plants (termed nothospecies), but some animals such as the red wolf (*Canis rufus*) are thought to have arisen through hybridization (in this case between grey wolves, *Canis lupus*, and coyotes, *Canis latrans*). The biological species concept is therefore not infallible when it comes to defining dividing lines between organisms, although the idea of reproductive isolation is important for explaining how species diverge in the first place.

On a practical level, it can be very difficult to demonstrate reproductive isolation between possible species, because both mating and the offspring produced must be observed. This problem is easier to overcome with captive animals than with wild ones, but even then mating can be difficult to induce (famously so in the giant panda, *Ailuropoda melanoleuca*), so a lack of observed mating does not necessarily indicate separateness (Fig. 5).

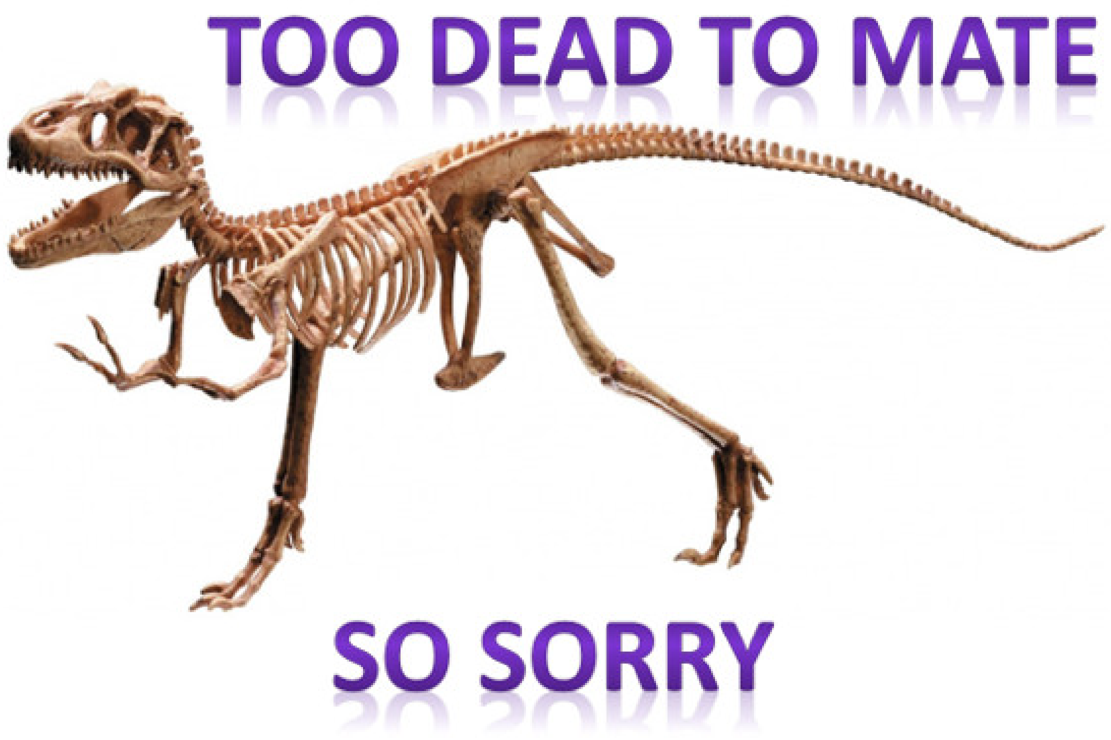

FIGURE 5 — TELLING DINOSAUR SPECIES APART CAN PROVIDE CHALLENGES. SOURCE.

In practice, a combination of factors is usually invoked to indicate reproductive isolation among animals. The factors include a lack of obvious hybrid individuals, non-overlapping breeding seasons, functional barriers (think of the Great Dane and Chihuahua), different mating calls, geographical separation and genetic divergence. Another line of evidence often used, especially if other biological information is lacking, is morphological (shape) differences; the assumption is that if two organisms look similar, they are probably closely related. This may be generally true, but there are several confounding factors that have to be taken into account. For example, two organisms might seem very similar, but may have evolved independently from different ancestors — a process known as convergence (Fig. 6). With careful study and experience this can usually be recognized, so it is not a big problem at the species level, because the organisms being compared are not usually closely related.

Another problem is that there is not always a correlation between genetic and morphological similarity. Two very different looking animals (such as the Great Dane and Chihuahua) may still be similar genetically, and, conversely, two near-identical animals may be very distinct genetically (Fig. 6). These latter animals are known as cryptic species, and are being discovered frequently in genetic reviews of populations once thought to belong to a single species. Thus, different types of data may give conflicting indications as to whether animals belong to separate groups. The best studies use multiple lines of evidence to create a consensus view on the status of different species.

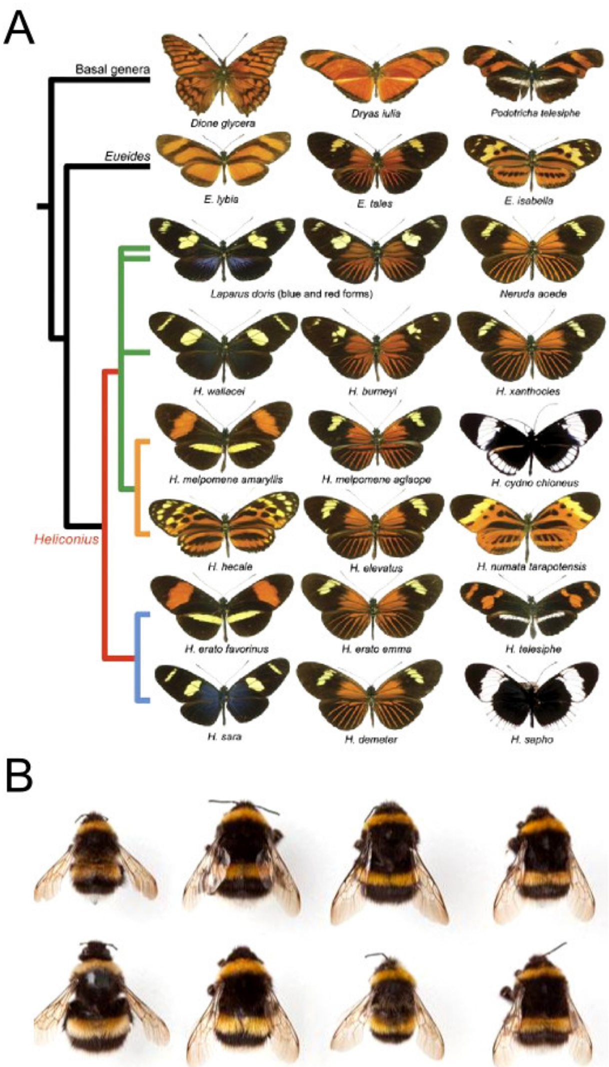

Figure 6 — (A) Convergence in the wing patterns of the butterfly genera Eueides and Heliconius. (B) Cryptic diversity within the bumble-bee genus Bombus. Source 1: M. Joron et al. 2006. Heredity 97, 157–167. Source 2.

Many of these trade-offs are irrelevant to palaeontologists, in a practical sense at least, because the only line of evidence available for fossils is morphology. However, there are fundamental differences between the comparison of shape in modern animals and that in fossils. For a start, biologists usually work with the whole animal or plant, so they have knowledge about external structures, colouration patterns, soft-tissue shape and distribution — whereas palaeontologists are usually limited to hard structures, such as bones or woody or shelly parts. Soft-tissue impressions may occasionally be preserved, but they are rare and are often dissociated from other structures, so are not that useful for separating closely related animals. Some progress has been made in mapping the colour patterns of feathered dinosaurs, but these restorations are still quite crude and suitable specimens are rare, so it is unlikely that these developments will be useful for taxonomic distinctions. Finally, the process of fossilization invariably distorts the shape of a fossil, whether because the animal is incompletely preserved or because the material has been crushed or deformed (Fig. 7).

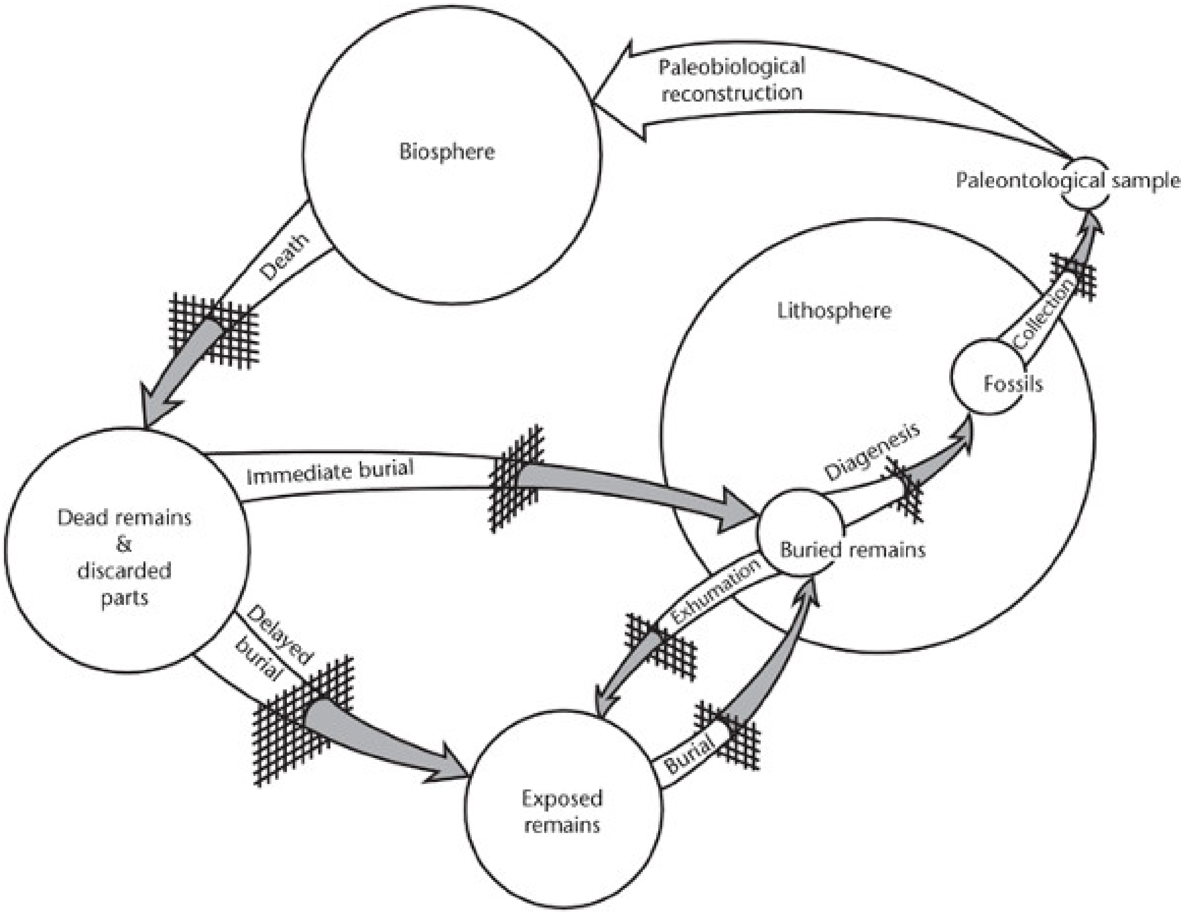

Figure 7 — Factors affecting the successful reconstruction of fossils. The cross-hatching represents a sieve, filtering out information on the organism at each step of the operation. These forces are known as taphonomic processes. Diagenesis is the changes that occur during fossilization, such as chemical alteration or mineral replacement. Sources: Behrensmeyer, A. K. and Kidwell, S. M. (1985) Taphonomy's contributions to paleobiology. Paleobiology 11: 105–119. via: Terry, R. C. 2009. Palaeoecology: Methods.

How do you define different?

In order for a discovery to be named as a new species, material must be compared to the type specimens of similar animals and judged to be significantly different. The definition of different can vary widely depending on the species concept used and the opinion of the person doing the work. Differences deemed significant by one person may be considered mere variations by another. This has led to the terms 'lumpers' and 'splitters' being used to describe personal philosophies towards naming new species and genera.

The practice of lumping, in which people tend not to name new species, can lead to the creation of 'wastebasket taxa' when one genus or species (usually one that was poorly defined to begin with) becomes a dumping ground for anything vaguely similar. For example, the dinosaur genus *Iguanodon* (meaning Iguana tooth), famous for its pointy, conical thumb spike, once included any animals with this structure (Fig. 8). Today it is recognized that a whole set of dinosaurs had this structure in varying forms, and the group Ankylopollexia (meaning stiff thumbs) was created for them. Things can swing the other way too, with splitters naming new species on the basis of very small differences. In the past five years, *Iguanodon* has gone from having four species to only one, with individuals previously included in the other three species having been upgraded to produce 12 new genera. None of these new genera are the result of discoveries of new skeletons, but are simply due to reviews of existing material and changing opinions on how much variation is acceptable in a group. As a result, the definition of a species is subjective, especially in palaeontology, where there are few lines of evidence to compare.

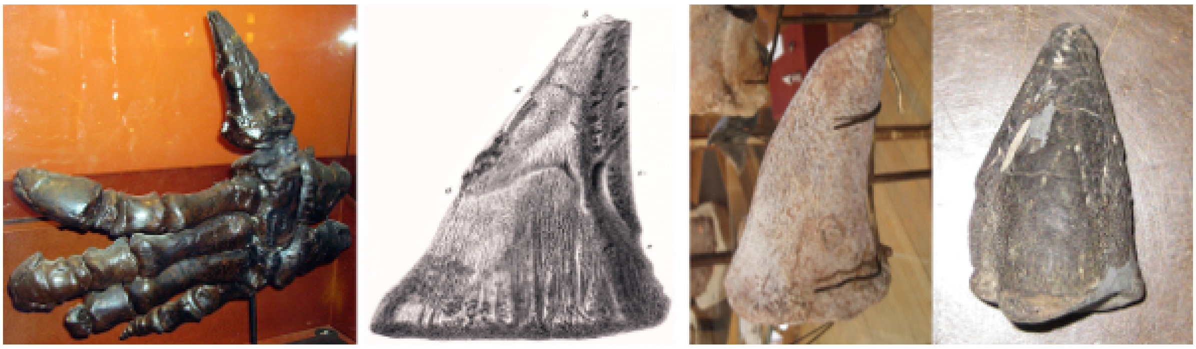

Figure 8 — Variation in the thumbs of iguanodont dinosaurs. In the past, the presence of this bone would have been enough to place them all in the genus Iguanodon. In early reconstructions, the structure was thought to be like a rhino horn and placed on the animal's nose.Sources: C. Marquart; Wikimedia Commons, Ballista; Wikimedia Commons, Jos. Dinkel; Wikimedia Commons, Ghedo.

It should now be becoming clear how the names of species can easily be changed, even without the discovery of new skeletons. In general, species that have been carefully compared to other related animals and described thoroughly from multiple, fairly complete specimens will stand the test of time. However, in practice, skeletons are often incomplete and it is rare to find multiple individuals. New species are often based on fragments of intriguing material, which can be easily separated from other known animals. This can cause problems later on, because the features that were so distinctive at first may not be enough to distinguish a species from closely related animals discovered later. This is particularly common with species named in the Victorian era, which were usually described briefly and from fragmentary material. Standards for description were much less regulated than they are now, and so little was known about these animals that even a piece of tooth was enough to separate one from all other fossils of the time.

A cautionary tale

One particularly infamous period in history of palaeontology is a feud known as the Bone Wars. Two Victorian palaeontologists, Othniel Marsh and Edward Cope, were between them responsible for the naming of hundreds of new species over a period of 30 years (Fig. 9). Much of what we know about the classic ancient animals of North America came from their feverish exploration of states such as Wyoming, Montana and Colorado. Marsh and Cope loathed each other so deeply that they went to great lengths to outdo each other in the quantity of species they could name. However, this has led to problems because many of their discoveries were described very briefly, or from little material, meaning that they are not fit for purpose. For example, a species of the herbivorous dinosaur *Camptosaurus* (flexible lizard) was named by Marsh in 1894, but characterized only as: "*Camptosaurus medius* was about 15 feet long". This kind of description or holotype that is unacceptable by modern standards is known as a *nomen dubium*, or doubtful name.

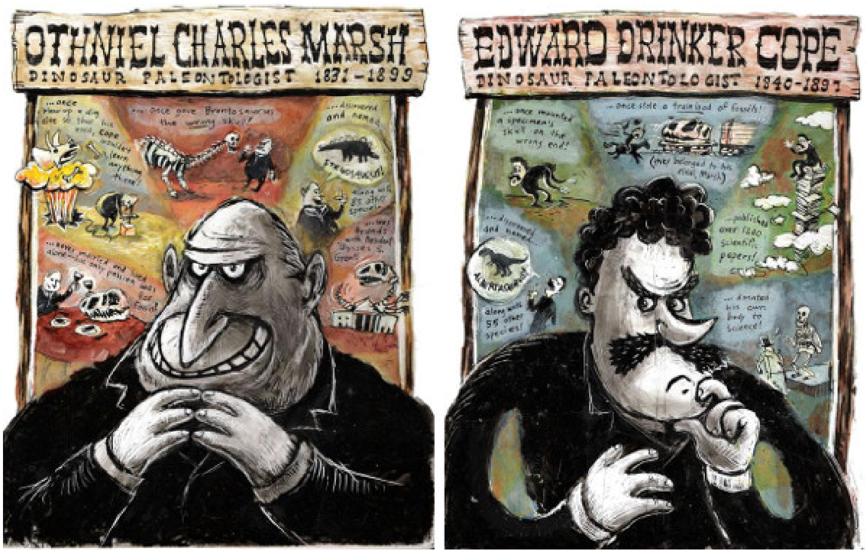

Figure 9 — A colourful look at O. C. Marsh and E. D. Cope. Source.

In other instances, descriptions and materials used by Cope and Marsh were better, but because of their mutual hatred, they refused to inspect each other's collections (although they did each send spies out in the field to discover where the other was digging). This has meant that both men frequently described the same animal independently, resulting in species having multiple names. When something like this is found to have happened, the first name to be published becomes the official name and all others are considered synonyms, in a process called synonymization.

Synonymization is what led to the demise of the *Brontosaurus* (thunder lizard). This sauropod (long-necked) dinosaur was described by Marsh in 1879 from a skeleton that was fairly complete but had no head. It was one of the Jurassic dinosaurs that Marsh selected to be part of a series of technical illustrations he commissioned in the 1880s, which included restorations of skeletons in life poses. He had to find a head for the dinosaur, so he assigned skull bones from another nearby quarry to *Brontosaurus*, even though none of these bones matched any parts in the rest of the skeleton. In fact, it was later discovered that this short-snouted skull belonged to an entirely different type of sauropod, and that *Brontosaurus* was from a group that had longer skulls (Fig. 10).

FIGURE 10 — THE CURRENT SKULL OF APATOSAURUS (TOP) AND AN OLDER RECONSTRUCTION OF BRONTOSAURUS (BOTTOM), SHOWING THE SHORT-SNOUTED SKULL INCORRECTLY USED TO REPRESENT THE ANIMAL FOR SO LONG. SOURCE: WIKIMEDIA COMMONS, KONSTABLE.

Although there were always suspicions that the illustrated head was not the correct one, it was not until the 1970s that it was realized that a *Brontosaurus* skull had been in a museum collection all along, labelled as another dinosaur. Using old letters from the time of excavation, it was possible to prove that this long-snouted skull was associated with the body of a *Brontosaurus* specimen from Utah. What people thought of as a *Brontosaurus* was therefore not a 'real' dinosaur, but made up of parts from two fairly unrelated animals — a mixture termed a chimaera. As a result, this species never existed in the form we know it.

Even without the skull problems, *Brontosaurus* had never been a valid species to begin with. Marsh had actually created another, similar dinosaur species called *Apatosaurus* (deceptive lizard) in 1877, although the description was brief and did not include any illustrations. When he came to name *Brontosaurus* in 1879, Marsh did not think that the two animals were related, because *Apatosaurus* was smaller. However, as early as 1903 it was concluded that *Apatosaurus* and *Brontosaurus* were the same animal — the smaller skeleton was just a younger individual. Because *Apatosaurus* was named first, it held the right of priority, so *Brontosaurus* was formally synonymized, and today lives on as (long-snouted) *Apatosaurus*. However, this name change was largely ignored, and when the first sauropod skeleton was mounted in 1905 under the name *Brontosaurus*, it captured the public's imagination (Video 1). People have been understandably loath to part with it ever since.

Video 1 — Gertie, the first animated dinosaur (Winsor McCay, 1914), was a Brontosaurus and did much to popularize the animal with the public. The skeleton mounted in 1905 was the inspiration for the film (as well as earlier appearances in McCay's cartoon strips) and can be seen from 1:00 onwards. The cartoon itself begins at 6:15.

In the end, many of Marsh and Cope's less glamorous creations suffered a similar fate: only about 20–30% of their species remain valid today, the rest having been synonymized or termed *nomina dubia*. These men represent the very extreme manifestation of the splitter mentality, but vigorous debate continues over what a species is, to this day.

Summary

The creation of new species is governed by many complicated rules introduced, in part, to undo problems created by early, less stringent work. Two-part names indicate the organism's genus (first) and species (second). Each full name is unique and the genus name must not have been used in the past.

The criteria used to define the species vary depending on what information is available. For living animals, they are usually evidence of reproductive isolation, such as genetic distance, and ecological or geographical isolation. However, these are not useful for organisms that do not reproduce though sexual means alone and are not testable for fossil animals.

Palaeontologists designate species according to observable shape differences, but these methods have many limitations, because information is often lost during the processes of fossilization and discovery. The definition of species is therefore more subjective in palaeontology, and the names of animals are less stable than in zoology.

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