Lesson 7: What is a Species?

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Learning objective for lesson 7: Students will learn the different ways of defining what a species is and will be able to compare the strengths and weaknesses of different species concepts.

Learning objective 7.1: Describe the requirements for erecting a new species.

In the late 18th century, the Swedish naturalist **Carl Linnaeus** did a great and enduring service to all biologists by introducing a new system for scientifically naming organisms. Linnaeus is considered to be the founding father of modern taxonomy. **Taxonomy** is the science of naming and organizing organisms into related groups. Prior to Linnaeus, there was not an agreed-upon system for assigning names to organisms, and this had led to considerable confusion. Under Linnaeus' system, which we still use today, every unique species of organism is given a binomial name.

The **binomial name** of a species consists of two parts: the **genus name**, or generic name, and the **specific epithet**. Here are two examples, the dinosaur *Tyrannosaurus rex* and our own binomial name *Homo sapiens*. *Tyrannosaurus* and *Homo* are the genus names, and *rex* and *sapiens* are the specific epithets. Note that the genus name is always capitalized and that the specific epithet is not. Also note that a binomial name is always italicized. Organisms that are different species but that belong to the same genus (meaning that they are very similar in overall form and are more closely related to each other than to members of any other genus) have the same genus name. For instance, our close relatives *Homo erectus* and *Homo habilis* share our genus name. Specific epithets may be shared by many organisms, regardless of how closely related they are. For instance, *Tyrannosaurus rex* shares its specific epithet with *Othnielia rex* (an ornithopod dinosaur), *Nuralagus rex* (a giant extinct rabbit), *Comitas rex* (a sea snail), and *Cattleya rex* (a flower). However, the specific combination of genus name and specific epithet are not permitted to be shared by any two species.

There are a few other rules governing how a species gets its binomial name. The **rule of priority** states that, once a species has officially been given a binomial name, the name cannot be changed (unless it turns out that the organism is not really a new species, in which case, the binomial name is abandoned). To officially give a new species a binomial name, a biologist must publish a description of the species in a widely distributed and peer-reviewed scientific publication and must designate a holotype specimen. The published description must include a list of characteristics or combination of characteristics that makes the new species unique. A **peer-reviewed** scientific publication is one that is not published until it has been reviewed by other scientists to verify that the contents of the publication are legitimate and scientifically reasonable. A **holotype** specimen is a physical example of the new species, and it must be kept in a research institution, such as a university or a museum, so that other scientists may study it and be able to both verify that it is a distinct species and compare it to other potentially new species that are later discovered. A holotype specimen does not necessarily need to be a complete specimen (a broken or partial specimen will do, as long as it shows the unique characters that make it a distinct species). Holotype specimens of dinosaur species are hardly ever complete.

As an example, the University of Alberta Laboratory for Vertebrate Paleontology houses the holotype specimen (UALVP 48778) of a small dinosaur called *Hesperonychus elizabethae*. The genus name is *Hesperonychus*, and the specific epithet is *elizabethae*. UALVP 48778 includes only a partial pelvis, but this pelvis provided enough information for palaeontologists to determine that it represented a new kind of dromaeosaurid theropod. The description of the new genus and species was published in the peer-reviewed journal *Proceedings of the National Academy of Sciences*.

Learning objective 7.2: Describe sources of morphological variation

You might think that identifying a new fossil species is as simple as pointing out the differences in the anatomy of two animals, and that's that. However, there are many reasons that one individual may look different from another individual, even if both belong to the same species! Individuals that differ in morphology because they belong to different species represent **interspecific variation**. Individuals that belong to the same species, but that have different morphologies, show **intraspecific variation**. There are several potential sources of intraspecific variation that we need to take into account when trying to identify a new species of dinosaur. First of all, males and females of the same species can look different, and this is called **sexual dimorphism** (or, sexual variation). Think about animals like deer, where the males have antlers but the females do not. There are many examples of sexual dimorphism in modern animals, and so dinosaurs may have exhibited sexual dimorphism as well.

Ontogenetic variation is the variation that you can see between young individuals and old individuals of the same species. Besides size differences, animals can change shape as they progress through ontogeny, which is a fancy way of saying 'as they grow up'. Puppies often have shorter snouts relative to their overall head size, compared to fully grown dogs. **Individual variation** is the normal variation that exists among individuals of a given species. Take humans, for example: we come in a variety of sizes as adults, and things like eye and hair colour vary among individuals. The last source of variation that we need to consider when thinking about fossils is not biological in origin, but geological: taphonomic processes like plastic deformation can change the shape of a bone, resulting in **taphonomic variation**

Learning objective 7.3: Identify the necessary types of evidence required to delimit species based on the biological species concept versus the morphological species concept.

Now that we have described how a species gets its name, we come to a serious question: what exactly is a species? There is no single definition or agreed-upon concept of what a species is. The most common species concept is the **biological species concept**, which defines a species as a group of organisms that can successfully interbreed. This species concept works well when applied to most modern animals and many plants. However, it cannot be applied to the majority of those modern organisms that reproduce asexually and which, therefore, cannot be said to interbreed at all. Nor can the biological species concept be applied to extinct organisms of any kind, since testing whether or not two fossils can mate is impossible.

To make matters even more complicated, a single species can sometimes be divided into separate groups by geographic barriers. Each of these geographically separate groups of individuals is called a population. A **population** is any grouping of organisms that live in the same geographic area and interbreed. One or more populations make up a single species.

Instead, paleontologists rely on the morphological species concept. The **morphological species concept** defines a species as a group of organisms that share a certain degree of physical similarity. In dinosaur paleontology, the morphological species concept is often applied as it relates to the biological species concept. That is, fossil specimens are assumed to belong to the same species if their physical similarities are consistent with the similarities that would be expected (based on the general pattern of physical similarity observed in modern species) between members of a group that can successfully interbreed.

Learning objective 7.4: Explain what types of evidence are available in the fossil record to define a species

You might think that identifying a new fossil species is as simple as pointing out the differences in the anatomy of two animals. However, there are several factors that may cause one individual to look different from another individual, even if both belong to the same species. Individuals that differ in morphology but belong to the same species are said to exhibit **intraspecific variation**.

Obviously, defining species using the morphological species concept is not an exact science, and trying to do so may be confounded by a variety of factors. Consider, for example, the taxonomic conundrum that a future paleontologist might face when discovering the skulls of an adult female moose, an adult male moose, and a juvenile male moose. Assuming that the futuristic scientist was not familiar with the sexual dimorphism and ontogenetic patterns of moose and their relatives, this paleontologist might be inclined to consider the more robust and antlered skull of the adult male moose to belong to a different species than the female and juvenile. The paleontologist might also be inclined to reason that the juvenile was just as likely to be a separate species of small deer or to be a juvenile form of either adult. Sexual dimorphism and ontogenetic change are both

Life restoration of *Hesperonychus* by Sydney Mohr, used with permission.

factors that make the morphological species concept tricky to apply, especially given the incompleteness of the fossil record.

Because of these and other confounding factors, there is considerable disagreement among paleontologists over how much of a morphological difference is needed to reasonably consider one species of dinosaur as distinct from another. Paleontologists who require more differences before they consider two species to be distinct are called **lumpers**. Paleontologists who require fewer differences before they consider two species to be distinct are called **splitters**. Whether you are a lumper or a splitter can have a big effect on the total number of dinosaur species you recognize and on your interpretations of dinosaur species diversity.

Let's finish off with another look at *Hesperonychus*. *Hesperonychus* is one of the smallest known dinosaurs from North America. How did paleontologists know that it was a new species, rather than an individual of an already named species? Since it is small, could it be a juvenile of another species?

The specimen had several unique features on the pelvis that were not seen in any other dromaeosaurid theropod, which suggests that it was a new species. Additionally, the bones of the pelvis were tightly fused together. In juveniles, the bones of the skull, vertebrae, and pelvis are not tightly fused together, and you can see the sutures between individual bones. The sutures were not visible in the *Hesperonychus* pelvis, suggesting that it was a fully-grown individual that had a small adult size. Sexual dimorphism is harder to test, but none of the differences in the pelvis seemed likely to relate to sex-specific functions. Finally, the pelvis was well preserved, and taphonomic deformation could not have produced the unique features. So, naming the specimen as the holotype of a new species seemed to be the right choice.

Supplementary Materials.

Understanding variation in and between species:

Laelaps: Out of many *Psittacosaurus*, one. [blog post]

Dinosaur Tracking – Goodbye, *Anatotitan*? [blog post]

Tetrapod Zoology - The explosion of *Iguanodon*, part 3: *Hypselospinus*, *Wadhurstia*, *Dakotadon*, *Proplanicoxa*...When will it all end? [blog post]

Tetrapod Zoology – Stegosaur Wars [blog post]

Optional: Royal Tyrrell Museum Speaker Series: Who-oplocephalus? *Euoplocephalus*! [video lecture]

New dinosaurs from Alberta!

Laelaps – New horned dinosaur had funky frill. [Blog post]

Dinosaur Tracking - Paleontologists welcome *Xenoceratops* to the ceratopsian family tree. [blog post]

Cleveland Museum of Natural History – Scientists name new species of dinosaur, "bone-headed" *Acrotholus audeti* [video]

Green Tea and Velociraptors – Theropod dinosaurs were waaay more diverse than previously thought. [blog post]