Biology Before Darwin: Crash Course History of Science #19

Crash Course: History of Science
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In physics, questions about astronomy led to revolutionaries such as Kepler and Newton, who provided a new theoretical framework that replaced the old Aristotelian one.

But when it came to the study of living things, this shift didn't happen until a little later, in the 1800s. You've probably heard of Charles Darwin, but before we get to him, and I'm excited to get to him, you really need to understand how different people, throughout the seventeenth and eighteenth centuries, tried to answer the same question: "what is life?" [INTRO MUSIC PLAYS} During the Scientific Revolution and Enlightenment, there was no biology—that term was first used in 1799.

Instead, there was natural history, the observation-based study of living things, based on the work of Aristotle. For Aristotle, living things were all of one kind, but animated by different types of soul. So, plants have a vegetative soul and can grow.

Animals have a sensitive soul and can move. And humans alone have a rational soul, capable of reason. Organisms could be compared by imagining their position on a great chain, leading upward in complexity and worth from grass to starfish to humans.

This Great Chain of Being gave people throughout Europe and parts of Asia and Africa a way to understand differences in form between things. But it didn't include an element of time. Did living things change over time?

That is, did they evolve? What sorts of evidence would prove this, and would this proof contradict the bible? Would God let extinctions happen!?

Let's set the stage for these questions, which would rock the world of natural history. Alongside the first microscopists, other brilliant people were creating knowledge about living things in the 1600s. Two notable natural historians jump out—a great experimentalist and a great observer.

In 1634, the Spanish Inquisition arrested Flemish alchemist Joannes Baptista van Helmont for the crime of… studying plants! He was put under house arrest, but this experience didn't deter him: like Galileo, it made him want to science even harder. Van Helmont really wanted to understand how plants grow, so he devised his famous willow tree experiment to provide some answers.

Van Helmont wanted to test the theory that plants grow by eating soil, so he weighed a willow tree—it was five pounds—as well as some soil—two hundred pounds of it. He planted the willow in the soil, in a pot, and then tended to the plant's needs, observing its growth over five years. After that time, he weighed the tree again, then dried the soil and weighed it, too.

The mass of the soil had remained the same over five years, but the tree's mass had significantly increased. Van Helmont concluded that the tree grew not by eating soil but by drinking water. Published in 1648, after Van Helmont had died, this willow-weighing became the first quantitative experiment in biology!

Another major seventeenth-century natural historian was Maria Sibylla Merian. Born in Frankfurt in 1647, Merian was the leading entomologist, or insect expert, of her day, as well as a highly skilled scientific illustrator. Merian became well known for her work on how some insects metamorphose, or change shape.

Her careful observations of the life cycle of the butterfly became a benchmark for other natural historians. In 1699, Merian traveled to the Dutch colony of Suriname in South America to study tropical insects. She was horrified by the slavery she encountered there, but was also aided by an enslaved person, which was typical of many European natural historians.

In 1705, Merian published the heavily illustrated Metamorphosis Insectorum Surinamensium, cementing her reputation in both art and science. The next major shift in natural history came thanks to Carl Linnaeus. Born in 1707, Linnaeus sought to discover the order of nature.

He reasoned that, if you could just compare every species along the same axis—say, sexual organs, or limbs—then you could create a gigantic table, showing every living thing on earth, side by side. Think about that supremely Enlightenment-style visual metaphor: life was a static table full of information. Lots of other people were trying to figure out how to classify living things.

But Linnaeus's system won out. Linnaeus invented the binomial system that biologists still use. The first name or genus represents a more general category.

The second name or species is based on a specific characteristic. Humans, for example, are Homo sapiens, or the "intelligent men," as opposed to our extinct relatives, Homo erectus, the "standing men," or our closest living relatives, the bonobos, who some scientists classify as Homo sylvestris—the "forest men." Linnaeus introduced the binomial system in Systema Naturæ in 1735. We can compare this text to Galileo's Two Sciences or Newton's Principia, in that it provided natural historians with a new paradigm for how to do their jobs.

Beyond the binomial, Systema also addressed higher-level classification. Say you encounter a thing. First, you decide on its kingdom—meaning whether it's an animal, vegetable, or mineral, as per tradition.

Then you assign it to a class, such as such as mammal or bird, and an order based on some characteristic, such as, say, eels or spiny-finned fishes. FYI, Linnaeus was the first to assign bats to Team Mammal instead of Team Bird. Then you assign genus and species.

And all of these decisions you make rationally, based on some observable and comparable feature: does the thing have wings or arms? Spines or no spines? How many ventricles in its heart?

Internal or external gills? Although it's evolved a lot over three centuries, we still use Linnaeus's system today! Linnaeus was called the "Second Adam" because he named so many organisms, mostly plants.

He didn't go out collecting plants, but he inspired a generation of European natural historians who did. They had a new tool at their disposal that allowed them to rapidly concentrate thousands of botanical samples in a small number of botanical gardens: empire. With tall-ships constantly sailing from London, Antwerp, Stockholm, and Calais for distant continents, the naturalists of the 1700s used military might to make knowledge about ecosystems that Europe didn't have.

A perfect example of a statesman–scientist who took advantage of colonial empire in order to fill in the table of nature was Sir Joseph Banks. Born in 1743, Banks became the preeminent British naturalist of his day. Appointed by the Royal Navy and the Royal Society, Banks sailed with James Cook aboard the HMS Endeavour from 1768 to 1771, traveling to Brazil, Tahiti, New Zealand, and Australia.

When he returned home, famous and full of ideas about the great variety of living things, Banks became advisor to the king on the Royal Botanic Gardens at Kew. He also rose to become president

of the Royal Society, holding the position for over forty years. In order to build Kew into one of the greatest botanical gardens in the world, Banks directed other botanists to travel the world, collecting plants, and bringing them back to the center of the British Empire.

There, they were classified using the Linnaean system and shown off to the public. So, Linnaeus was hugely influential in thinking about how to classify organisms, and Banks pushed the powerful British Empire to make tabulating nature a project of prestige. But they didn't raise deep epistemic questions about what living things are, like if species change over time or not.

Those questions would come into the mainstream of science thanks to a trio of French thinkers who we can think of as the "Transformists": Buffon, Lamarck, and Cuvier. Georges-Louis Leclerc, AKA the Comte de Buffon, was born in 1707. He became superintendent of the Royal Garden in Paris and argued with Thomas Jefferson about whether animals and plants in the Americas were inferior to those in Eurasia. (We'll come back to the Americas.) But, importantly for natural history, Buffon thought that living things are degenerating, or slowly becoming worse than God originally designed.

He didn't provide a mechanism for how this devolution worked, and he later recanted his controversial views. But Buffon did at least open the door among well-connected, university-trained philosophers to the idea that species changed. This idea was pushed further by a more humble botanist.

Jean-Baptiste Lamarck, born in 1744, he was a peasant, but he became a professor of invertebrates: actually, he coined the term "invertebrate!" Lamarck was an expert on marine worms and marine snails, mostly focused on shells. Although he also published Flowers of France, in 1778. And, influenced by Buffon, Lamarck criticized the fixity of Linnaeus, moving toward an evolutionary theory.

Thought Bubble, What did that theory look like? The reason we remember Lamarck as the almost-Darwin is that he developed a specific theory of "transformisme" to describe how species changed—providing a how and, perhaps more importantly, a why. Lamarck believed that individuals inherited the traits that their parents had acquired during life.

In life, individuals use certain body parts more than others, changing them ever so slightly, and then pass those changed parts down to their kids. Although this idea has been proven wrong since Lamarck's time, some historians still credit him with essentially predicting epigenetics, or changes in living things made by changes to which gene are expressed rather than by changing the genetic code itself. Gradually, Lamarck thought, creatures would become more complex.

This progressive evolution was the opposite of Buffon's devolution. Lamarck's famous example was the giraffe: according to Lamarck, its neck elongated as the animal stretched up to reach leaves that were higher on trees. Over time, short giraffes grew slightly longer and slightly longer necks until—voila—they could reach those high leaves.

Of course, Lamarck never actually studied or even saw a giraffe—although he almost got the chance. The Pasha of Egypt had given France a giraffe in 1827, shortly before Lamarck died… but after Lamarck had gone blind. Lamarck's transformisme was not exactly a full framework for doing natural history.

But he did argue that, essentially, the environment is what pulls an organism along into a new form… which makes historiographical sense. After all, Lamarck lived in a setting of rapid, radical change for humans like himself: the French Revolution. He saw the transition from a post-Revolution republic into the empire of Napoleon Bonaparte.

And he saw how different individuals responded to environmental shifts. Thanks, Thought Bubble. Finally, there was Georges Cuvier, born in 1773, and he added a different wrinkle to the theory of biological transformation: extinction.

Cuvier was an immensely famous professor, known as the "Napoleon of natural history." Cuvier met Ben Franklin, corresponded with Thomas Jefferson, and advised the real Napoleon. Scientifically, Cuvier established modern comparative anatomy as a discipline, specializing in the study of elephants. Cuvier believed each species was perfectly adapted to its environment, and that you can reconstruct an organism from only one or two bones, if you understand how anatomical systems function.

Cuvier opposed any theory of evolution, vigorously arguing against Lamarck's progressive one. But Cuvier also built his entire personal scientific empire on the careful study of fossilized animal remains, comparing living and dead animals and classifying them by their bone structure. He could see that some types of animals simply no longer existed!

How did Cuvier square the fossil record with a belief in a divinely ordered, mostly unchanging creation? He argued for catastrophism, the idea that major changes in species come about due to catastrophic events—such as the Flood of Noah. At the end of the 1700s, natural historians had a system for comparing and naming everything alive.

They had state support. And they had some ideas about how life changed over time. But they didn't have a new paradigm for researching this change.

They didn't have a biology. Next time—let's follow the fossil trail, hunt for mines, learn the true age of the earth, and further clear the way for Darwin's biology: first, we need the birth of geology! Crash Course History of Science is filmed in the Dr. Cheryl C. Kinney studio and is made with the help of these nice people and our animation team is Thought Cafe. Crash Course is a Complexly production.

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