16.2

Welcome to Lesson 16.2, "Ideas That Shaped Darwin's Thinking." In this lesson, we'll identify the conclusions drawn by James Hutton and Charles Lyell about Earth's history; we'll describe Jean-Baptiste Lamarck's hypothesis of evolution; we'll describe Thomas Malthus's view of population growth; and we'll explain the role of inherited variation in artificial selection. Charles Darwin was profoundly influenced by the work of other scientists. The *Beagle*'s voyage came during one of the most exciting periods in the history of science. Geologists were studying the new observations and inferences about forces that shape our planet. Naturalists were describing and analyzing connections between organisms and their environments. These and the other new ways of thinking about the natural world helped shape and guide Darwin's thoughts as he proposed hypotheses and gathered data to test them.

Many Europeans in Darwin's day believed Earth was only a few thousand years old and that it hadn't changed much. By Darwin's time, however, a new generation of geologists were thinking in very different ways about Earth's history. Geologists James Hutton and Charles Lyell proposed important hypotheses based on the work of other researchers and on data they uncovered themselves. Hutton and Lyell concluded that Earth is extremely old and that the processes that changed Earth in the past are the same processes that operate in the present. In 1785, Hutton presented his hypotheses about how geological processes have shaped the earth. Lyell, who built on the work of Hutton and others, published the first volume of his work, the *Principles of Geology*, in 1830. Hutton recognized the connections between a number of geological processes and geological features, like mountains, valleys, and layers of rock that seem to be bent or folded.

Hutton realized that certain kinds of rocks are formed from molten lava. He also realized that some other kinds of rocks form very slowly, as sediments build up and are squeezed into layers. Hutton also proposed that forces beneath Earth's surface can push rock layers upward, tilting or twisting them in this process. Over long periods, those forces can build mountain ranges. Mountains, in turn, can be worn down by rain, wind, heat, and cold. Most of these processes operate very slowly. For these processes to have produced Earth as we know it, Hutton concluded that our planet must be much older than a few thousand years. These data and inferences moved him to introduce a concept called deep time--the idea that our planet's history stretches back over a period of time so long that it is difficult for the human mind to imagine. Charles Lyell's great contribution was to argue that laws of nature are constant over time and that scientists must explain past events in terms of processes they can observe in the present.

This way of thinking, called uniformitarianism, holds that the geological processes we see in action today must be the same ones that shaped Earth millions of years ago. Ancient volcanoes released lava and gases, just as volcanoes do now. Ancient rivers slowly dug channels and carved canyons, just as they do today. Lyell's theories, like those of James Hutton before him, required enough time in Earth's history for these changes to take place. Like Hutton, Lyell argued that Earth was much older than a few thousand years. Otherwise, how would a river have enough time to carve out a valley? Darwin had begun to read Lyell's books during the voyage of the *Beagle*, which was lucky. Lyell's work helped Darwin appreciate the significance of an earthquake he witnessed in South America. The quake was so strong that it threw Darwin onto the ground.

It also lifted a stretch of rocky shoreline more than three meters out of the sea--with mussels and other sea animals clinging to it. Some time later, Darwin observed fossils of marine animals in the mountains thousands of feet above sea level. Those experiences amazed Darwin and his companions, but only Darwin turned them into a startling scientific insight: he realized that he had seen evidence that Lyell was correct. Geological events like the earthquake, repeated many times over many years, could build South America's Andes Mountains--a few feet at a time. Rocks that had once been beneath the sea could be pushed up into the mountains. Darwin asked himself, "If Earth can change over time, could life change too?" Charles Darwin wasn't the first person to suggest that species could evolve. The fossil record already provided strong evidence that life had changed over time. Ideas differed, however, as to how change happened.

The French naturalist Jean-Baptiste Lamarck proposed two of the first hypotheses. Lamarck suggested that individual organisms could change during their lifetimes by selectively using or not using various parts of their bodies. He also suggested that individuals could pass these acquired traits on to their offspring, enabling species to change over time. Lamarck published these hypotheses in 1809, the year Darwin was born. Lamarck proposed that all organisms have an inborn urge to become more complex and perfect. As a result, organisms change and acquire features that help them live more successfully in their environments. He thought that organisms could change the size or shape of their organs by using their bodies in new ways. According to Lamarck, a water bird could have acquired long legs because it began to wade in deeper water looking for food. As the bird stretched its legs to stay above the water's surface, its legs would grow little longer.

Structures of individual organisms could also shrink if they were not used. If a bird stopped using its wings to fly, its wings would become smaller. Lamarck called traits altered by an individual organism during its life *acquired characteristics*. Lamarck also suggested that if a bird acquired a trait, like longer legs, during its lifetime, it could pass that trait on to its offspring, a principle referred to as *inheritance of acquired characteristics*. Today, we know that Lamarck's hypotheses are completely unsupported. Organisms do not have an inborn drive to become perfect. Evolution does not mean that a species becomes "better" over time. Also, evolution does not progress in a predetermined direction. We also know that traits acquired by individuals during their lifetime, such as a loss of a limb, cannot be passed to offspring.

Still, Lamarck was one of the first naturalists to argue strongly that species are not fixed. He was among the first to propose a scientific description of natural processes he thought could enable species to change over time. Lamarck also recognized that organisms' adaptations are related to their environment and the way they "make a living." So, although Lamarck's hypotheses explaining evolutionary change were wrong, his ideas paved the way for later biologists, including Darwin. In 1798, English economist Thomas Malthus noticed that humans were being born faster than people were dying, causing overcrowding. Malthus reasoned that if the human population grew unchecked, there wouldn't be enough living space and food for everyone. The forces that work against population growth, Malthus suggested, included war, famine, and disease. Darwin was thunderstruck when he read Malthus's work.

He realized that Malthus's reasoning applied even more to other organisms than it did to humans, because all organisms have the potential to produce many more offspring than can survive. A maple tree produces thousands of seeds each summer. One oyster can produce millions of eggs.

If all the descendants of any species survived for several generations, they would overrun Earth's limited natural resources. Obviously, this doesn't happen. Most offspring die before reaching maturity, and only a few survivors reproduce. Darwin combined ideas about population growth with observations that individual organisms in nature differed from one another. Plant and animal breeders confirmed his observations. Some plants bear larger or smaller fruit than average for their species. Some cows give more or less milk than others in their herd. Farmers also told Darwin that some of these differences were inherited variation. Farmers used this variation to their advantage.

They would select for breeding only trees that produced the largest fruits or cows that produced the most milk. Over time, this selective breeding, which Darwin called **artificial selection**, would produce trees with even bigger fruits and cows that gave even more milk. In artificial selection, nature provides the inherited variations, and humans select those variants they find useful. Darwin tested artificial selection himself by raising and breeding plants and pigeon varieties. Darwin had no idea how heredity worked or what caused inherited variation, but he did know that inherited variation occurs in wild species as well as in domesticated plants and animals. Before Darwin, scientists thought variations among individuals were simply unimportant, minor defects. Darwin made a breakthrough by recognizing that inherited variation was extremely important, because it could provide raw material for a *natural* mechanism that could drive evolution.

Finally, Darwin had all the information he needed. His scientific explanation for evolution was formed. When it was published, it would change the way people understood the living world.