



THE EVOLUTION REVOLUTION

The story of how one of science's greatest ideas came into being is both remarkable and riddled with myths. John van Wyhe lifts the lid

Evolution is the most revolutionary concept in the history of science. Nothing else has more radically changed our understanding of the natural world and ourselves.

The work of Charles Darwin showed, irrefutably, that humans are just another animal occupying a small branch on a vast tree of life. No divine spark is needed to explain our existence and traits.

But how exactly did Darwin devise his theory of evolution? What ideas did he build on? Where does the naturalist Alfred Russel Wallace, who proposed a similar theory, fit in? And how shocking was the idea to the Christian society of the time?

The story of the uncovering of this great revelation has been retold countless times since the publication of Darwin's *On the Origin of Species* in 1859. In the process, the assumptions and guesses of one generation became accepted as fact by the next – with some spawning widespread myths. Perhaps the most fundamental of these is that thinkers had been striving for centuries to solve the mystery of the origin of species. They hadn't, and indeed they couldn't have – just as ancient Greek philosophers could not have been searching for dark matter.

Traditionally, people in Christian Europe had believed that the world was about 6000 years old. This view was guided by interpolations from the Bible, which itself gave no date for creation. Gradually such beliefs were modified by Christian thinkers based on new information about Earth, gleaned from the growth of mining and the development of geology. By the early

19th century it was widely understood that Earth could not be a few thousand years old, but must be inconceivably ancient.

Earth was also found to have changed over time. Close study of rocks and fossils revealed a complex history of different ages. One layer of the geological record might show lush tropical vegetation populated with reptiles unlike any alive today. In the rock layers just above, yet another terrestrial world might have existed with different animals and plants. To explain this, in 1812 the great French anatomist Georges Cuvier put forward the idea that each age

had been abruptly ended by some great catastrophe.

Another puzzle was the discovery in Europe and America of gigantic fossilised animals. Where could creatures such as mammoths be living today? Perhaps their kind had died out? This couldn't be true, according to traditional belief, since God would not allow any of his created species to perish.

Cuvier's detailed research in anatomy established, once and for all, that creatures such as the mammoth were not the same as anything alive today, and were extinct. For us, extinction is such a mundane fact that we cannot

appreciate how radical the concept was initially. However, it soon became almost universally accepted in the scientific community, with one important exception: the French naturalist Jean-Baptiste Lamarck.

For Lamarck, these unfamiliar fossil forms had not gone extinct. Instead they had changed, evolving into something else – although his view of this process was different to that later proposed by Darwin (see "The view before Darwin", below). The mammoth, for example, could have evolved into the elephant.

As the influential Cuvier did with so many rivals, he used his reputation to demolish Lamarck. The result was that for the first few decades of the 19th century, not only Lamarck's theory but any theory of evolution was considered unscientific and absurd. Although Lamarck won a few converts, many more accepted Cuvier's view that a succession of eras of life had come and gone.

But where did the new species that emerged after these extinctions come from? The geologist Charles Lyell argued in his *Principles of Geology*, published in the early 1830s, that slow processes had changed Earth over time. Lyell's picture was one of perpetual change. As an environment gradually transformed, the species that lived in it would become unsuited to it and die out, because there was a limit to how much they could change to adapt. Just how new species arose was left vague.

Lyell's work was of great interest to Charles Darwin, a young Cambridge graduate who was appointed to join the surveying voyage of HMS Beagle

THE VIEW BEFORE DARWIN

Lamarckism is mentioned in biology textbooks as shorthand for a pre-Darwinian theory of evolution in which species were thought to evolve via the inheritance of characteristics acquired during an organism's lifetime. According to this, the giraffe got its long neck by intentionally stretching to reach the top of trees. This slightly stretched neck was then passed on to offspring, and so on. But this version of Lamarckism is a terrible caricature. The biologist Jean-Baptiste Lamarck did not originate this idea – which many naturalists, including Darwin, continued to accept – and this was not the core of his theory. Instead, Lamarck's central idea was that there is a tendency for life to progress up the scale of perfection according to a "complexifying force". New species originated continuously via spontaneous generation (the appearance of life from inorganic matter) and could adapt to local circumstances through the inheritance of acquired characteristics.



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Galapagos Islands finches: were they key to Darwin's ideas?

as a naturalist in 1831 (contrary to popular accounts, he was not invited along to be the captain's social companion, nor was the ship's surgeon the official naturalist). During this five-year voyage, Darwin matured into one of the most experienced scientists of his generation. He worked primarily as a geologist but also collected a wide range of living things, from finches to fungi.

The expedition first visited South America, then surveyed the waters around the Galapagos Islands. Only in the middle of the 20th century did Darwin's visit there come to be portrayed as a pivotal moment in his life. He never described it as such. And as charming as it sounds, there is no truth to the story that Darwin noticed the beaks of the finches were adapted to different diets and that this provoked his evolutionary theorising. There was no Galapagos eureka moment.

After the return of HMS Beagle in 1836, Darwin set to work describing his mountain of specimens. He also began asking himself deep questions about nature, life and religion. Gradually, he gave up his belief in Christianity. "It is not supported by evidence", he concluded. Nevertheless, as far as we know, he never lost a belief in a supernatural creator behind nature.

Several types of evidence led Darwin to accept that species must evolve. On his voyage down the South American continent, he observed that related species gradually replaced one another. The species living in the Galapagos also puzzled him. Many of these were unique to the islands, yet most were strikingly similar to South American species. But the Galapagos, a collection of marine volcanoes, had never been connected to South America and their climate was totally different.

According to Lyell's view, species were somehow created to suit new environments. So why

ROUTE TO A BREAKTHROUGH

- 1795** Erasmus Darwin, Charles's grandfather, foreshadows Darwin when he writes: "Would it be too bold to imagine that all warm-blooded animals have arisen from one living filament... with the power of acquiring new parts"
- 1798** The doom-mongering *An Essay on the Principle of Population* by Thomas Malthus warns of the dire consequences of unrestricted population growth. It is a key influence on Charles Darwin
- 1809** French naturalist Jean-Baptiste Lamarck publishes *Philosophie Zoologique*, outlining his idea of evolution according to a "complexifying force"
- 1809** Charles Robert Darwin is born in Shrewsbury, UK, the fifth of six children in a prosperous family
- 1813** French zoologist Georges Cuvier publishes *Essay on the Theory of the Earth*, setting out his idea that new species appear after catastrophes such as floods
- 1823** Alfred Russel Wallace is born in the village of Llanbadoc near the border of England and Wales, the seventh of nine children
- 1831** Darwin sets sail on HMS Beagle for a survey of South America. The voyage lasts five years
- 1837** Darwin sketches the first "tree of life" in his notebook to explain the evolutionary relationships between species
- 1848** Wallace departs for an expedition to Brazil. On the return journey four years later, a fire destroys many of his specimens
- 1858** Wallace conceives of his theory of how species adapt to a changing world. On 1 July both Wallace's and Darwin's ideas are presented at the Linnean Society of London
- 1859** Darwin's *On the Origin of Species* is published and becomes the object of much ridicule and abuse
- 1860** Debating evolution at Oxford, Bishop Samuel Wilberforce asks Thomas Huxley, a champion of Darwin's ideas, if Huxley's monkey ancestors were on his grandmother's or grandfather's side
- 1870** Evolution comes to be accepted as fact by most of the international scientific community

“The implication that human beings must have evolved from earlier species was objectionable to many”

weren't the Galapagos species were so obviously related to South American ones instead of just being rocky island species? Darwin's explanation was that their ancestors must have come from South America and changed over time.

In 1838, Darwin read Thomas Malthus's 1798 *An Essay on the Principle of Population*, which argued that continued population growth would lead to famine and starvation. Darwin was struck by the implications of checks to population growth. This led him to focus on what allowed some individuals rather than others to survive and pass on their characteristics.

He hypothesised that every organism varied in many small ways, and any of these variations that helped or hindered would make a difference to which survived. He eventually called this filtering process “natural selection” by analogy with the process in which farmers changed domesticated plants and animals by selecting desirable individuals to breed from. In so doing, they emphasised some traits and reduced others (see “Evolution in a nutshell”, opposite)

It would take Darwin more than 20 years to publish these ideas. In recent decades it has become widely believed that Darwin kept his evolutionary theorising a secret and delayed its publication because he was afraid of the reaction. A large body of literature emerged proposing reasons for this: for example, that he was put off by the fierce reception to the 1844 evolutionary potboiler *Vestiges of the Natural History of Creation*, or that he was afraid of offending his religious wife.

Yet there is not a shred of evidence for either suggestion.

In fact, Darwin told his family, friends and colleagues about his theory and his plans to publish it. He felt he had years of research to conduct before he would be ready and, like his other major works, the species theory took longer than he originally imagined. By early 1858, he had drafted many chapters and was about a year or two away from publishing his “big book”, which would have spanned several volumes.

WORDS FROM WALLACE

Then, on 18 June, something surprising happened. An essay arrived in the mail from Alfred Russel Wallace, outlining a theory almost identical to Darwin's own.

Wallace was a brilliant collector who had worked in Southeast Asia since 1854. There are perhaps even more myths about him than Darwin. Wallace is often portrayed as

the lower-class underdog to the genteel, moneyed Darwin. But Wallace was not working class, and neither was he forced to leave school early because of his family's finances. He was not deprived of his proper share of credit or made the victim of skulduggery by Darwin or his cronies, as is often claimed today. The underdog version of Wallace's story emerged only after the 1950s.

Wallace had long been privately convinced that species must evolve. But he was certainly not, as many modern commentators put it, searching for a mechanism for how evolution works. As he collected thousands of tropical insects and birds, his theoretical views gradually matured.

In February 1858, on the tiny spice island of Ternate, Wallace lay sweating from fever when he thought of a means whereby species could become naturally adapted to a changing world. It was a filtering process of life and death that was very similar to

Darwin's natural selection. When he recovered, Wallace wrote an essay, “On the tendency of varieties to depart indefinitely from the original type”, aimed primarily at Lyell's anti-evolutionary arguments. Shortly after, Wallace received an encouraging letter from Darwin stating that Wallace's hero, Lyell, admired Wallace's work. This led Wallace to send the essay to Darwin with the request that it be forwarded to Lyell.

It has been claimed that Darwin might have lied about when he received the essay, leading to accusations that Darwin could have plagiarised Wallace. In fact, Darwin received the essay exactly when he said he did.

Darwin was struck by the resemblance between Wallace's views and his own. The same day, Darwin sent the essay on to Lyell, bemoaning that he ought to send it for publication ahead of his own work. For someone who was ever the Victorian country gentleman (see “Getting to know Darwin”, opposite), it seemed like the noble thing to do.

Lyell and another of Darwin's peers, Joseph Dalton Hooker, did not agree with that view. They had been aware of Darwin's theory for years and were not prepared to withhold their knowledge of Darwin's priority. They proposed a compromise: to present Wallace's essay together with some of Darwin's unpublished writings at a meeting of the Linnean Society of London. Modern opinions about these arrangements can be strong indeed, especially among those who think Wallace was unfairly treated. This is another mid-20th century view. According to the standards of the



In further Instant Experts on evolution, we look at the future of evolution and how genetics became incorporated into our understanding of Darwin's ideas.

time, however, the arrangement was fair. Wallace had sent his essay without asking for it to be kept private. The conventions of the day allowed Darwin or Lyell to publish it. Wallace was always accorded the honour of being the co-discoverer of natural selection and never tired of expressing his gratitude and satisfaction.

These brief writings of Darwin and Wallace offered the first statement of how species came into existence by natural means, yet they made remarkably little impact. Urged to bring out a reduced overview of his massive work in progress, Darwin spent 13 months condensing his 20 years of study into a single volume. This was published on 24 November 1859 as *On the Origin of Species*.

The book was immediately controversial and widely reviewed and discussed. Darwin came in for a great deal of ridicule and abuse. The implication that human beings must have evolved from earlier species was particularly objectionable to many, as was

the revelation that no divine guiding hand was needed; species evolve on their own.

But Darwin also gained strong support especially from members of the younger generation of naturalists, such as Thomas Henry Huxley (today always referred to as Darwin's bulldog, but not known as this in his lifetime). Darwin's mass of evidence, ranging from embryology and vestigial organs to geographical distribution, and his arguments in favour of evolution were overwhelming.

Despite its baptism of fire, *On the Origin of Species* almost single-handedly convinced the international scientific community that evolution was a fact. In his 1889 book *Darwinism*, Wallace wrote of the revolution Darwin effected: "this totally unprecedented change in public opinion has been the result of the work of one man, and was brought about in the short space of twenty years!"

The theory of evolution has come a long way since. Today we think of it in terms of genes and DNA, but Darwin and Wallace had no idea of their existence. It was only in the 1930s and 1940s that genetics was incorporated into evolutionary theory. Even now, new discoveries are shaking up our understanding, but at the core of the modern theory remains Darwin's idea of descent with modification.

Today evolution has many critics outside the scientific community, especially in the US, where a significant percentage of the population are creationists. What is forgotten is that the scientific debate over evolution was over by the 1870s and has never again been a matter of serious dispute. **n**

EVOLUTION IN A NUTSHELL

Darwin's and Wallace's theory of evolution maintains that new species are descended from earlier ones. This long-term process happens because all organisms vary. The tiny variations are naturally "selected" by virtue of whether or not they help an organism to survive the brutal struggle for existence in nature. Many are born, but few survive; fortuitous variations are preferentially passed on. This process of endless filtering works to adapt organisms to their environment.

GETTING TO KNOW DARWIN



William, Charles Darwin's eldest child, was also the subject of his father's studies

For someone who devised a revolutionary idea, Charles Darwin lived a remarkably quiet life. In 1842, Darwin and his wife Emma moved from London to rural Kent in southern England. They already had two children then, and would go on to have eight more.

Darwin had very regular habits. He rose early and went for a walk. After breakfast he worked in his study until 9.30 am, his most productive time of the day, then read his letters lying on the sofa before returning to work.

At midday he would go for another walk accompanied by his dog, stopping at his greenhouse to inspect his botanical experiments. Then he would proceed to the sand walk, a gravel path around a strip of woodland. While strolling on this "thinking path", Darwin would ruminate on his unsolved scientific problems.

After luncheon he read the newspaper and wrote letters. His network of correspondents provided information from all corners of the globe.

The Darwins were not very strict parents and the children were apt to run wild. Their mild-mannered father worked patiently to a background of playful screams and little footsteps stampeding past his study door.

After dinner Darwin played backgammon with his wife. They were very competitive. He once wrote, "Now the tally with my wife in backgammon stands thus: she, poor creature, has won only 2490 games, whilst I have won, hurrah, hurrah, 2795 games!"

Despite poor health, Darwin continued to publish a string of innovative and seminal works until his final book on earthworms in 1881. It was an instant bestseller. He died the following year, aged 73.

But science had one last claim on him. Rather than a quiet interment in the local churchyard, which he called "the sweetest place on Earth", Darwin was given a state funeral in London's Westminster Abbey.

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