

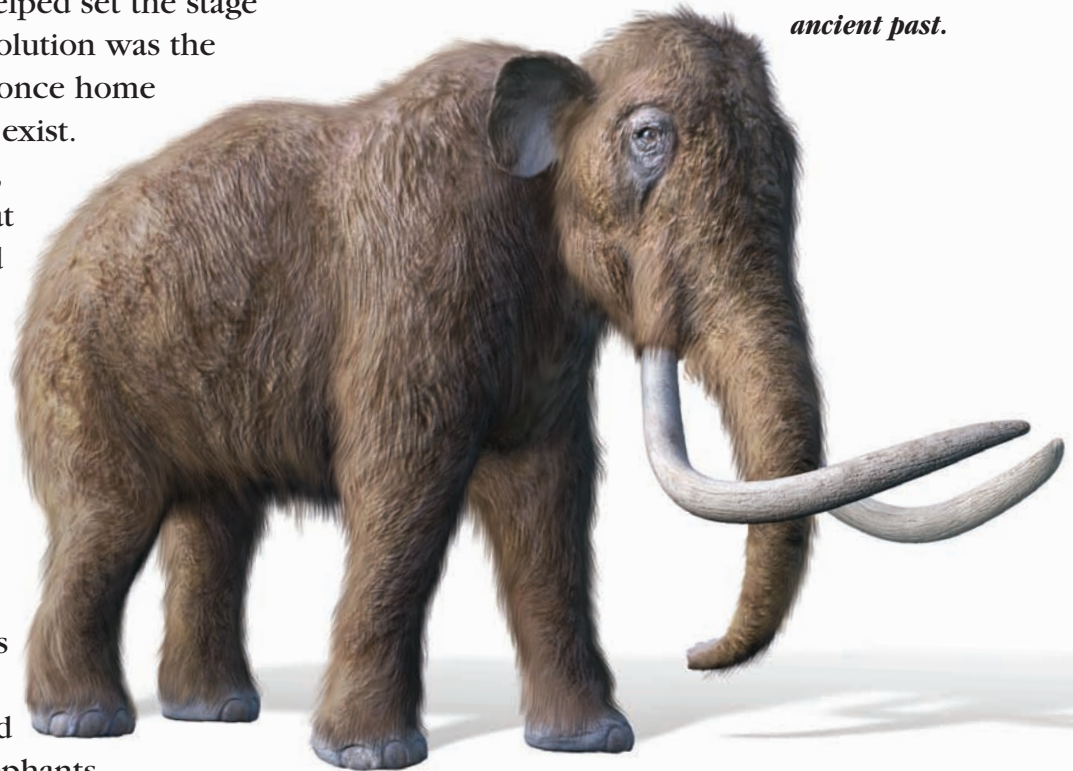
CLUES TO THE PAST

One breakthrough that helped set the stage for Darwin's theory of evolution was the discovery that Earth was once home to animals that no longer exist.

For hundreds of years, many people believed that all creatures were created at the same time, and that all of them were still around. Neither of these ideas turned out to be true.

For example, a mammoth may look like a modern elephant, but it isn't one. Scientist Georges Cuvier proved that in the 1790s, when he compared fossil mammoths with elephants alive today. Mammoths were not only different from elephants — they had “gone extinct.” They had died out and vanished from the Earth.

Mammoths helped prove that different animals existed in the very ancient past.

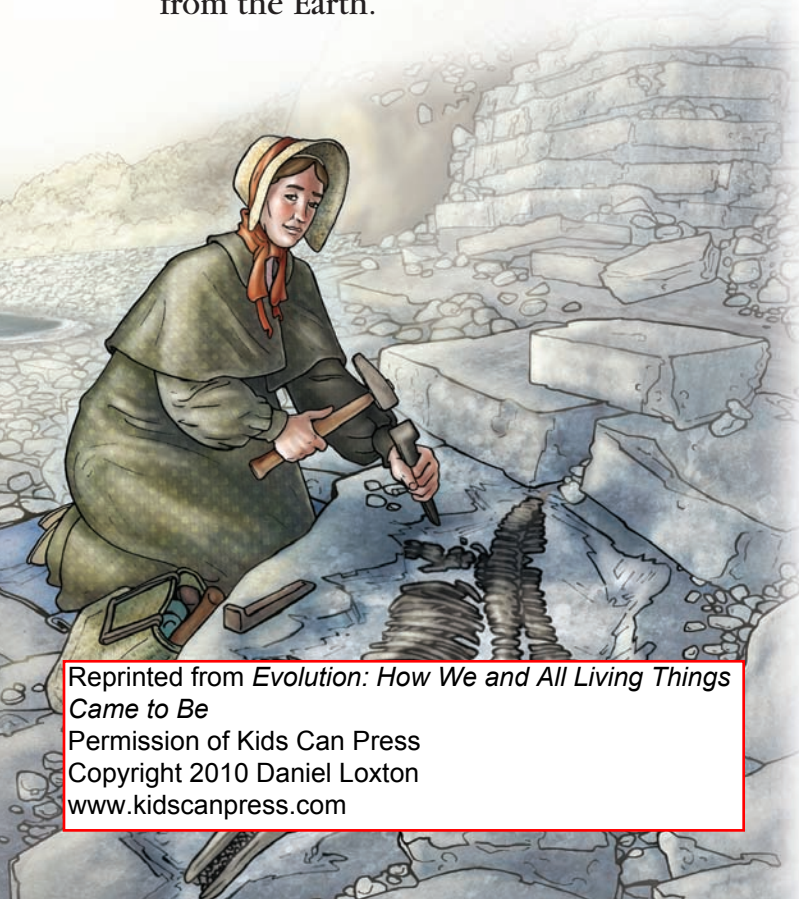


The idea that some animals had become extinct was confirmed when people found strange fossils totally unlike any living animals. One fossil hunter was a young English girl named Mary Anning. Around 1810, she discovered the first complete specimen of an extinct ichthyosaur — a reptile with a sharklike body streamlined for life in the sea.

Anning went on to find other important fossils. She was one of the great fossil hunters of all time.

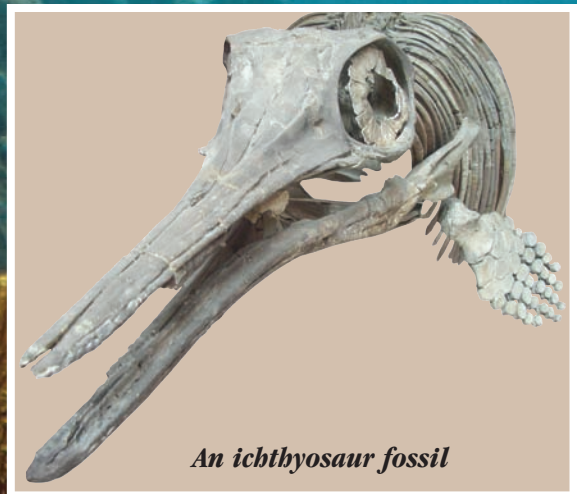
The fossils discovered by Anning and others were a real shock to people. During very ancient times, Earth was home to many kinds of animals that had since gone extinct. Fossils provided rock solid evidence that life was different in the past.

But how far in the past? And what sorts of changes had occurred in living things during Earth's long history?



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Ichthyosaurs were reptiles that evolved shark-shaped bodies. They ruled the sea for 150 million years, during the age of the dinosaurs.



An ichthyosaur fossil

ENTER CHARLES DARWIN

The clues were there, but no one had yet figured out what they meant. Then, in 1831, a young Englishman named Charles Darwin set out on a sailing ship called the *Beagle* — a voyage that would eventually lead him to solve the mystery of evolution.

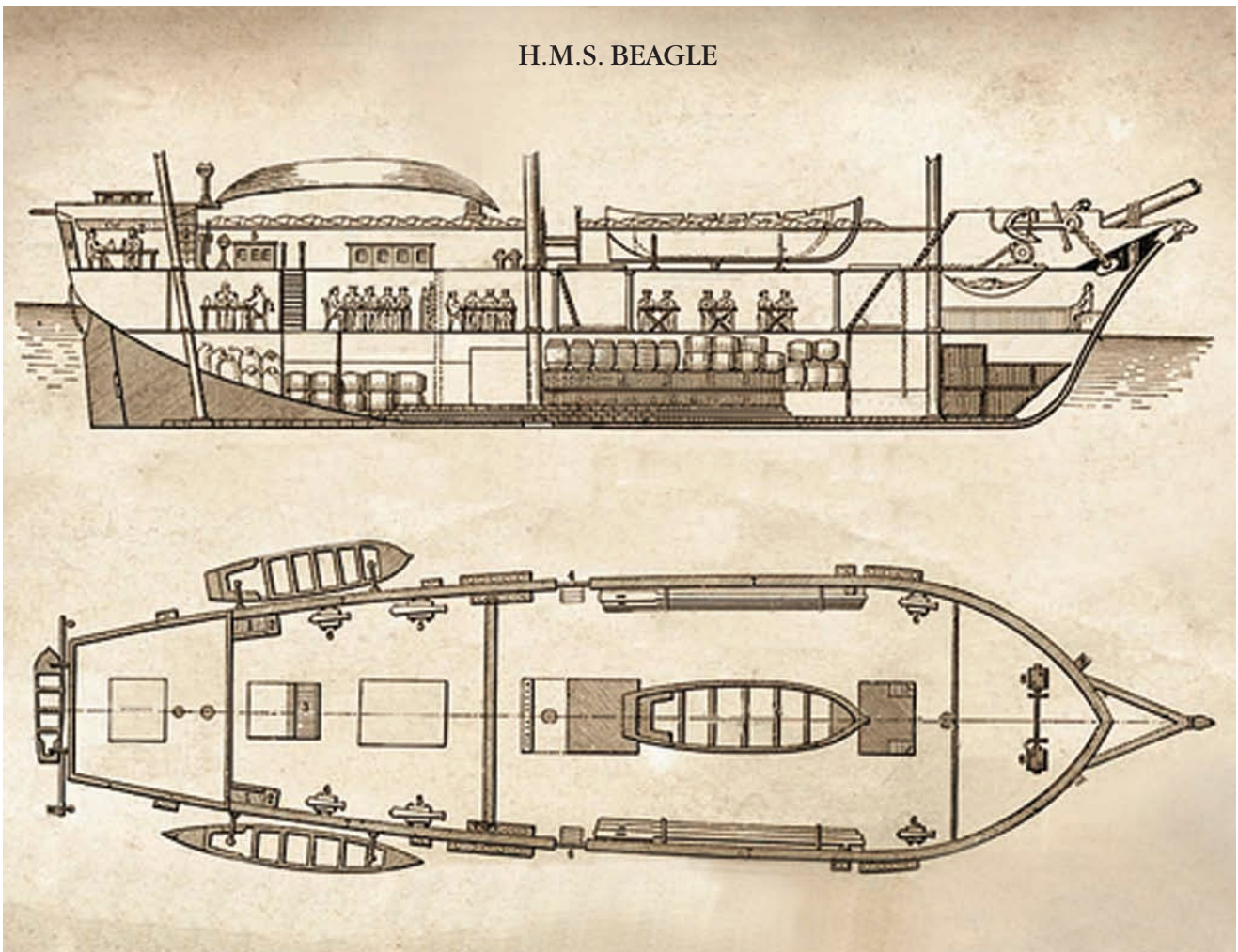
A medical school dropout, Darwin was a rich kid with a passion for the natural world. It was his interest in science that led him to volunteer aboard the *Beagle*, which was on a map-making mission around the globe.

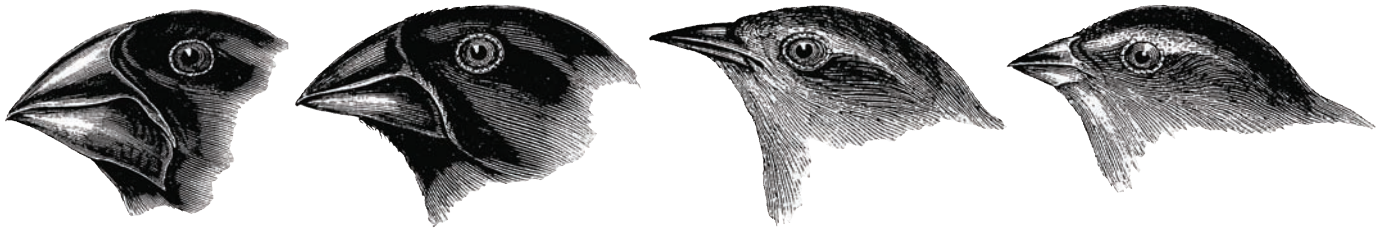


Darwin's job was to keep the captain company at dinner and to collect plant and animal specimens at the places they stopped.

While on the isolated Galápagos Islands (a chain of volcanic islands off the coast of South America), Darwin collected tortoises and birds. He took specimens from several of the islands. Later, in England, a bird expert noticed something remarkable — although the birds looked different, they were actually all finches.

H.M.S. BEAGLE





Darwin came up with a theory to explain why the finches looked so different from one island to another. He theorized that long ago, mainland finches had been blown to the islands. Once there, they developed different adaptations to take advantage of the different foods available to them. On one island, the finches had large beaks for cracking tough seeds. On another, they had long thin beaks for catching insects and so on.

But if that was true — if one species could turn into several new species — how did it happen?

Finches' beaks are adapted to the different foods available on various Galápagos Islands.



“What exactly is a species?”

A species is a group of living things that can reproduce with one another, but not with other life-forms. Cobras can breed only with cobras, giraffes with

giraffes and ivory-billed woodpeckers with other ivory-billed woodpeckers. (Try breeding a shark and a poodle and you're going to be out of luck.)

For most animals and plants, this is the most useful definition of species. But this definition doesn't work for some life-forms — especially microscopic ones. Some of these life-forms don't breed together at all. Instead, they reproduce by splitting into two.



HOW CHANGE HAPPENS

Darwin noticed that plants and animals had traits that made them more or less likely to survive. He also knew that parents could pass their traits on to their offspring. But how did new traits come about?

And how were traits passed on to the next generation? In Darwin's time, 150 years ago, people could only guess. Today, we know that it's all in the genes.

Inside every cell of every living thing (including you) is a long, complicated chainlike molecule called DNA. It contains the chemically coded instructions — called “genes” — for growing that living thing. Your genes instruct your cells to divide in a way that gives you certain traits. For example, you might have genes for curly hair or straight, blue eyes or brown and so on — everything that makes you who you are.

Many people describe this genetic code as being like a blueprint. After all, DNA does include instructions for building something. But biologist Richard

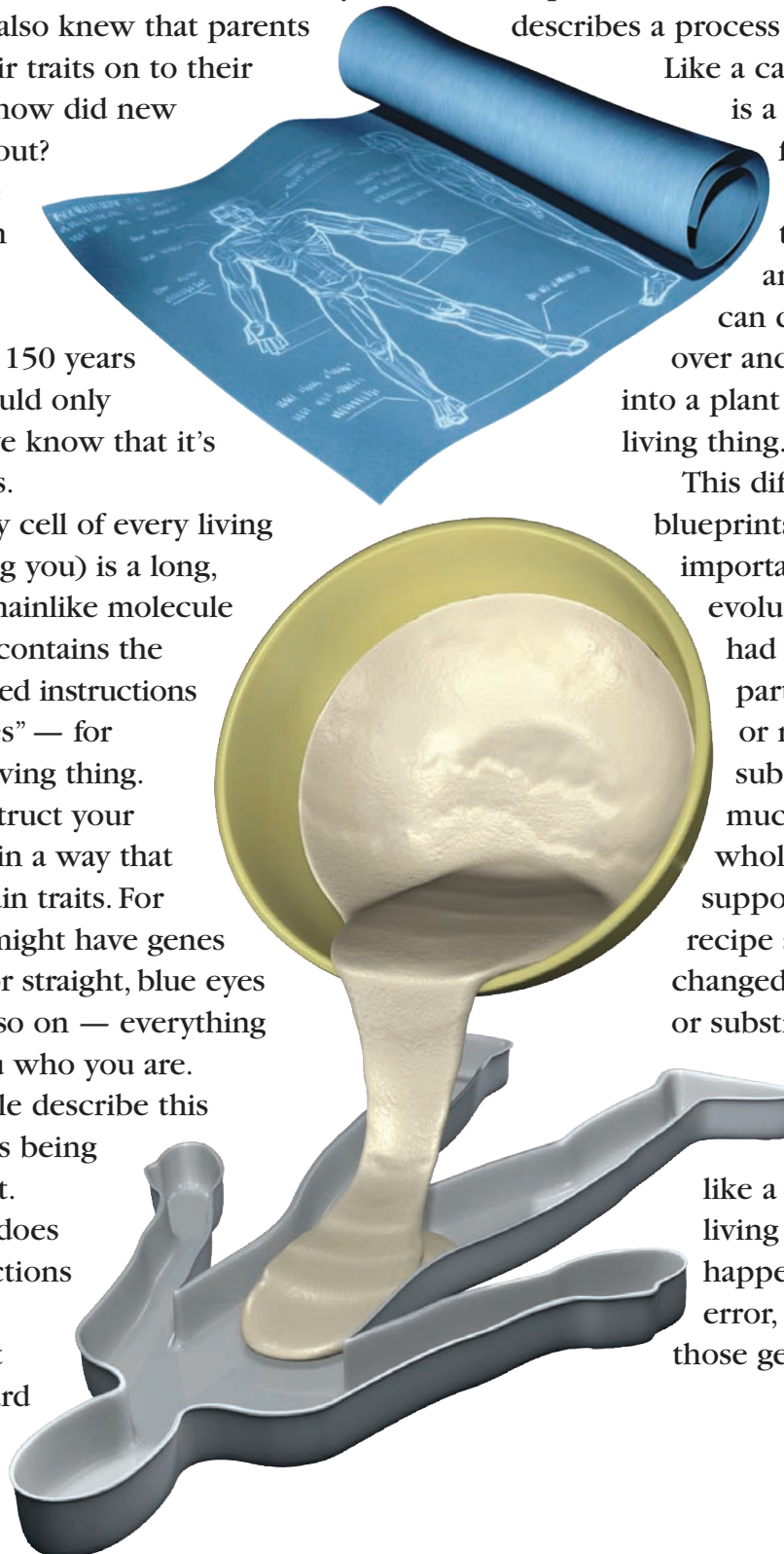
Dawkins thinks DNA is more like a recipe. A blueprint describes a thing, but a recipe describes a process for making a thing.

Like a cake recipe, DNA is a set of instructions for a process of development. If those instructions are followed, a cell can divide over and over and eventually grow into a plant or animal or other living thing.

This difference between blueprints and recipes is important for understanding evolution. If living things had blueprints, one part could be moved or redesigned or substituted without much affecting the whole organism. But suppose you misread a recipe and accidentally changed the cooking time or substituted salt for sugar.

You would change the entire cake.

So, DNA is a lot like a recipe for growing a living thing. And change happens when there is an error, called a mutation, in those genetic instructions.



We're All Mutants

You are a result of mutations — and so is every other living thing.

A mutation is an accidental, permanent change in the genetic instructions for making a living thing. Because mutations are random changes, they can have either harmful or helpful effects. For example, some women have a mutation that makes them much more likely to get breast cancer. Some other people have mutations that protect them from diseases such as River Blindness, which, as its name suggests, can cause blindness.

A mutation can have a big or small impact or no detectable impact at all. It all depends on which DNA instructions are changed, and how big those changes are.

Some genetic instructions are so important that any change will be bad. For example, all animals share a “master gene” for growing eyes. Changes to that gene result in deformed eyes — or no eyes at all.

Genetic instructions are delicately balanced, so sudden large changes are likely to cause problems. On the other hand, small mutations have a reasonable chance of being neutral (not harmful) and may even be helpful. For example, many people carry the harmless mutation that causes blue eyes. Another mutation makes a few fortunate people immune to the virus that causes AIDS.

When you're talking about mutations, the smaller the better. But, as time passes, many small changes can add up to big differences.

“Mutants” in the movies can have superhuman body parts and abilities or super-bad personalities and looks. These fantastic exaggerations are inspired by the real biological idea of “mutation,” or random genetic change.





“Can we ever see evolution happening?”

Yes. Occasionally, we *can* watch evolution in action. Take the peppered moth, which is found in

many parts of England. Most of these insects were light colored with dark pepperlike speckles, while a rare few were dark all over. The common peppered pattern was good camouflage against the light-colored bark and lichens on the trees where the moths liked to rest. The less common darker moths were easier for birds to spot and gobble up.

That was true until the Industrial Revolution, which started in the late 1700s. As people began to burn more coal to power new factories, coal smoke spread

over the countryside. It killed the light-colored lichens and blackened the trees with soot. When the moths' habitat darkened, the light peppered pattern stopped being good camouflage. Instead, the peppered moths now stood out more than the dark moths, making them easy prey for hungry birds.

Suddenly, dark moths had a better chance of surviving and breeding. The dark coloring stopped being a problem and became an advantage. This advantage was passed along to new generations.

Within a hundred years, almost all the moths were dark colored. A change in the environment led to a physical adaptation in the moths. That's natural selection and evolution in action!

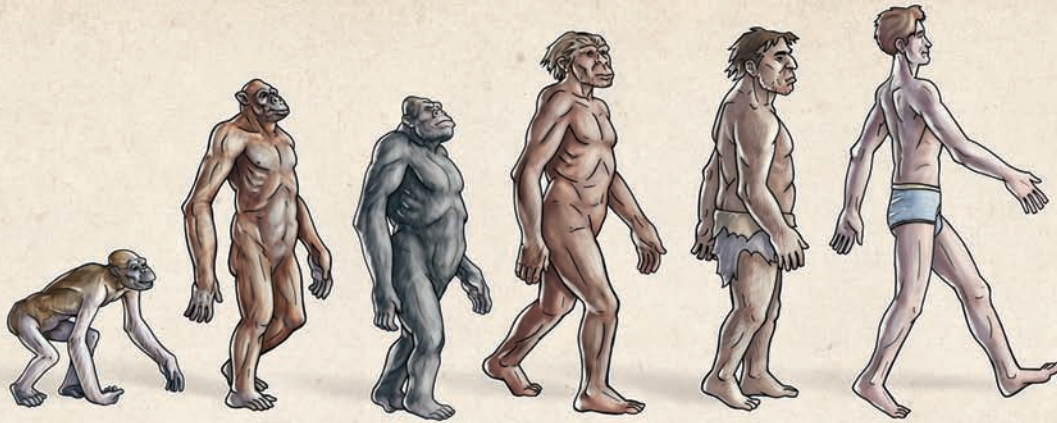


Moths with this speckled pattern were most common because they had better camouflage ...



... until coal pollution altered their environment. Then the previously rare darker moths had the advantage, and soon became the most common type.

MARCH OF PROGRESS



Don't be fooled by this drawing showing evolution as a simple "March of Progress." The real story of human evolution is far more complicated, and scientists are still working on piecing it together. Although we know that the fossils of ancient human relatives *are* related, we're still working out exactly *how* they are related.

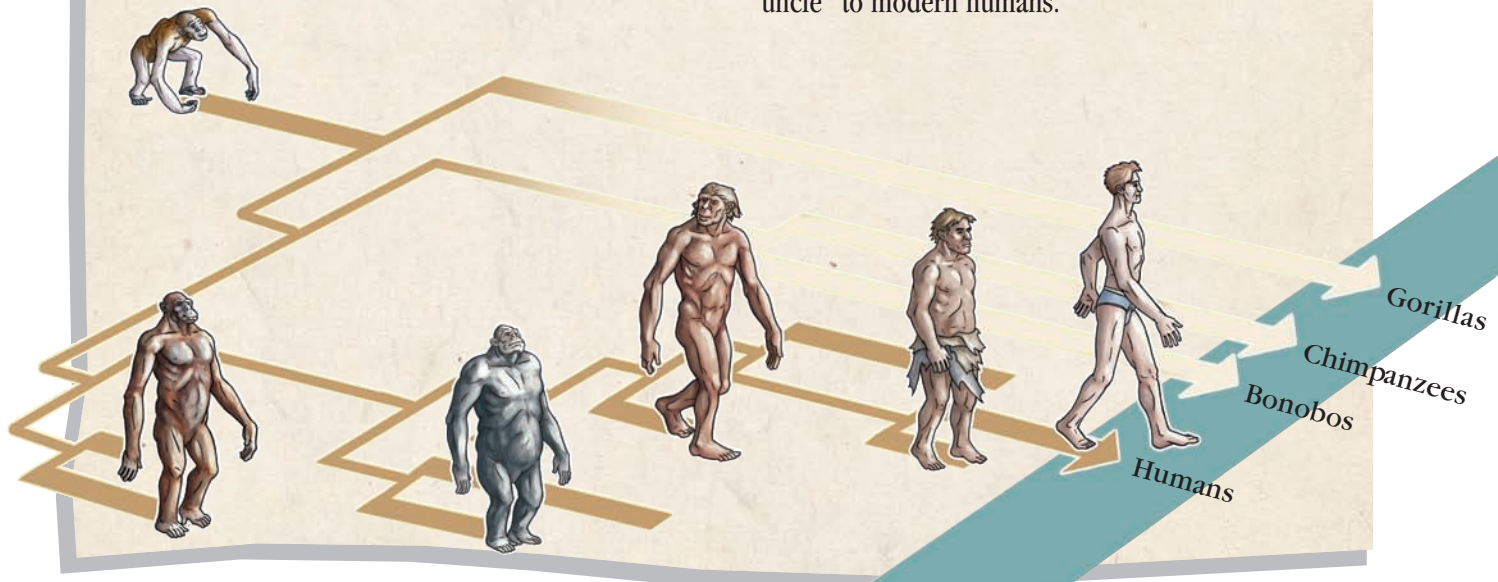
We can tell that ancient hominids are related to us by studying their skeletons, teeth and other evidence. We can also arrange the many species of extinct human relatives on a timeline: This species is older than that species and so on.

But knowing that one fossil is *older* than a related fossil doesn't tell us whether it is a *direct ancestor* of the other fossil. Think of your own

family: Your father and your uncle are both closely related to you, and they're both older than you. But you're *descended* only from your father — not from your uncle.

The same is true for fossils. We can often tell that Species A was descended from either Species B or a close relative of Species B. But we can't say for sure which one.

Consider the Neanderthals. These human relatives were powerful, muscular hunters who lived in Europe until they went extinct about 30 000 years ago. Scientists are still working out whether Neanderthals are among our ancestors, or if they were a separate species *related* to our ancestors. DNA evidence now strongly suggests that Neanderthals were just an "uncle" to modern humans.





“How could evolution produce something as complicated as my eyes?”

Yes, eyes are complicated. They have many parts that work together: an auto-focus lens, an iris to control the amount of light entering the eye, a bunch of little muscles to control the direction of our gaze and so on.

Some people argue that eyes could not work if any part were missing. For example, they say an eye without a lens couldn't focus. Therefore, eyes could not have evolved in small steps from simpler designs — they had to be made all at once. Goodbye, Darwin!

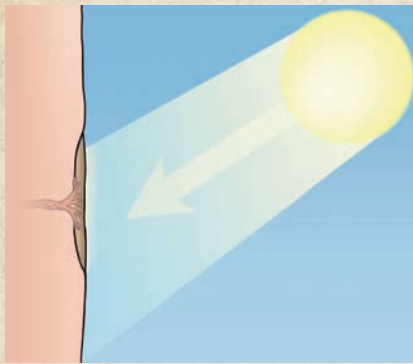
This might sound pretty convincing, except for one thing: It's just not true that eyes need all those parts to work. As Darwin pointed out, nature today is full of eye designs much simpler than ours.

For example, there are worms with clusters of light-sensitive cells on their skin. These cells let the worms tell night from day. Then there are animals such as flatworms with eyes that are simple dents lined with light-sensitive cells. These cells can detect the direction light comes from and even detect motion.

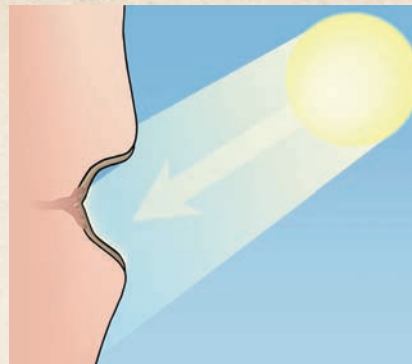


This sea creature, called a flatworm, has many simple cup-shaped eyes on its body.

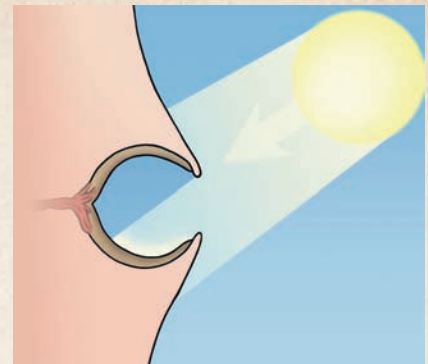




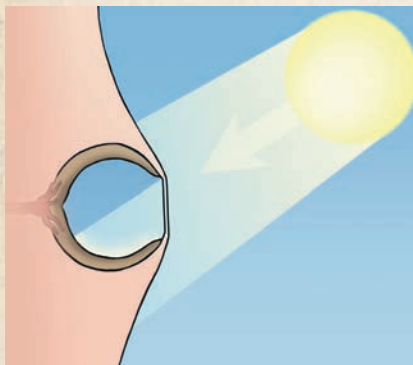
Simple light sensitive cells ...



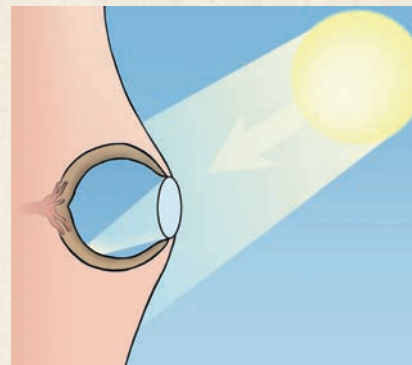
... lead to cup-shaped eyes ...



... that lead to pinhole eyes like those of the chambered nautilus.



A transparent cover develops to protect the eye ...



... which leads to crude lenses ...



... and finally to high-quality lenses like ours.

Some animals have deeper cup-shaped eyes that give them better vision, although it's still extremely blurry. But simply narrowing the opening of cup-shaped eyes fixes that problem. A narrow "pinhole" opening helps focus, even without a lens. (Some photographers use pinhole cameras that work in exactly this way.) In nature today, a squid relative called the chambered nautilus has this type of pinhole eye.

Then there are animals whose pinhole eyes are sealed over and protected by a bit of transparent skin. Any slight bulge in this transparent covering creates a crude lens that helps focus light. This happens in many animals today, including the apple snail. It's easy to see how top-quality lenses like ours could evolve — any improvement in the clarity or focusing power of the lens is a step in the right direction.

These many kinds of eyes illustrate the series of tiny steps that could slowly transform ordinary skin cells into complex human-type eyes. Every step works. Every step is an improvement. And every step is found in animals alive today.

The pinhole eyes of the chambered nautilus are just open hollow spaces with no covering lens.

