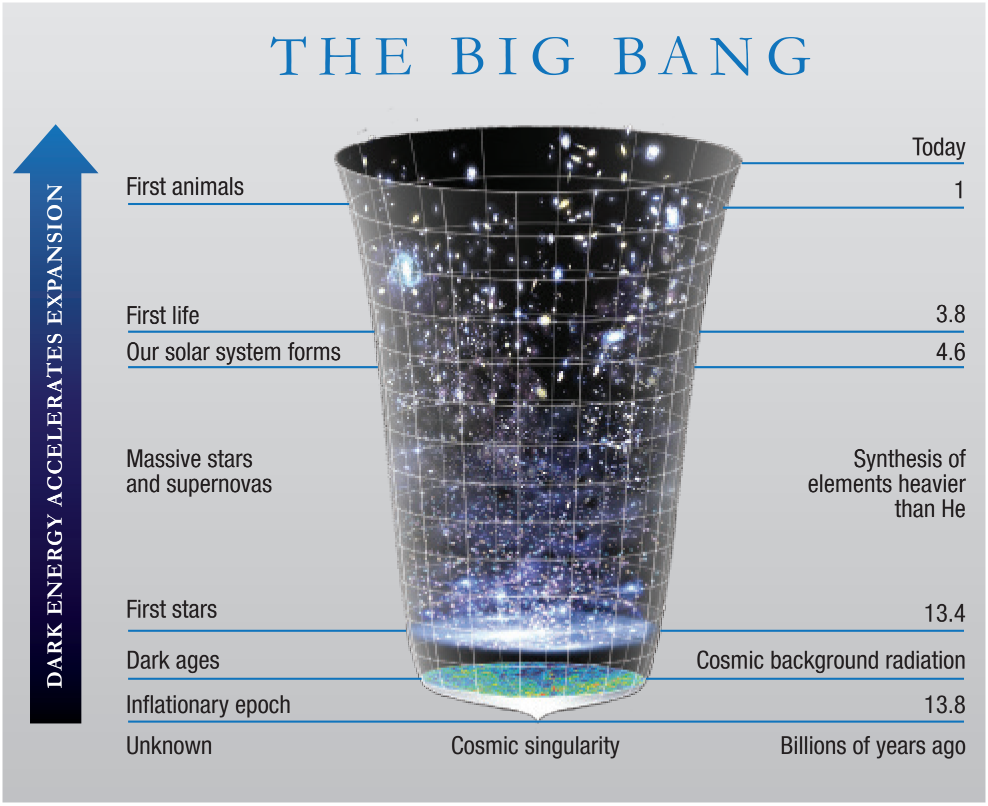
1 Abiotic to animal

Therefore I should infer from analogy that probably all the organic beings which have ever lived on this earth have descended from some one primordial form, into which life was first breathed.

Charles Darwin, *Origin of Species*

It took a long time and a lot had to happen before anything even remotely resembling us lived on Earth. Earth started out as a hot, uninhabitable planet without life (abiotic), but over the deep eons of geological time an amazingly rich diversity of life evolved. The story of our origins starts here with a brief, sweeping account of the events leading up to the emergence of the first animals on Earth. Placing human evolution within the context of the remote and distant past underscores just how recent our arrival is and, more importantly, that our arrival depended on all those who came before us. Our origin can ultimately be traced back to the first forms of life through the fact that we are related to and share many features with all other life. As expressed early on by Charles Darwin and later succinctly captured by Bill Bryson as 'All life is one', this profoundly unifying and big-picture feature of evolution is often unappreciated. Not only do we embody a rich history of past evolutionary events, but our arrival depended upon them. Thus, understanding how we came to be requires going right back to the very beginning.



Deep time: the big bang expansion as a cone of time, space and matter

In the beginning

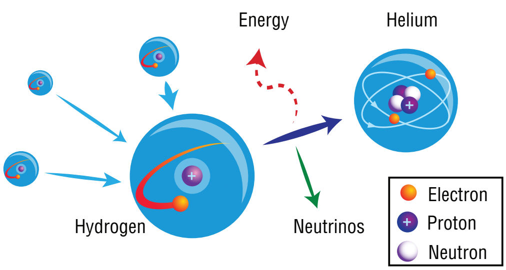
Every story has a beginning, a starting point from which all past events cascade to the present. Our story begins at the event furthest back in time that we are able to go, to the limit of what science can inform us about the origin of anything at all. A more grandiose beginning is hard to imagine, let alone comprehend. It all started at literally a point, called a cosmic singularity, into which everything we observe in our universe – space, energy and matter – was somehow squeezed. Out of this point our universe began expanding outward as the big bang approximately 13.8 billion years ago. What everything was doing at this single point, how it all ended up there, where it was before then and why it started expanding when it did are all unknowns. What we do know is that time, and hence our story, starts with the big bang.


The night sky

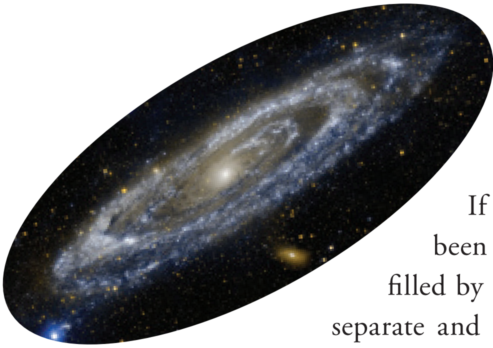
It is not at all apparent to us while stargazing into the tranquil night sky that we too are riding on the throes of this ongoing cosmic explosion of energy and matter. But the multitude of seemingly stationary twinkling points of light, which include the 100 billion galaxies of our observable universe, are hurtling through space at incredible speed. And they show no sign of slowing down. In fact, they are accelerating faster and faster away from one another at speeds approaching that of light, occupying an ever more enormous universe. It is owing to the vast distances that we are unable to perceive the incredible speeds at which all those light sources are receding away from us. But astronomers are able to measure the speeds and the distances and find that the stars and galaxies furthest away are moving fastest. If the paths of expansion of all the stars and galaxies we can see are run in reverse, they all end up together at a single point, a cosmic singularity, approximately 13.8 billion years ago. This is not to imply that it all started here – the observable universe would appear to converge on any observer no matter where in the universe he or she is.

What would an observer looking from outside our universe have seen as the big bang unfurled? In the initial fraction of a second, known as the inflationary epoch, a flash of exponential expansion at speeds exceeding that of light took our universe from the subatomic to cosmic scale. After this initial flash of pure energy, the universe continued to expand, but at more pedestrian speeds not exceeding that of light. As it expanded, it cooled. Within 20 minutes the universe had cooled enough to allow the conversion of some energy into atomic matter. The atom to form first was hydrogen, the lightest and simplest element, consisting of a nucleus with a single proton enveloped by a single orbiting electron.

In these first minutes while space was not too big, some of the hydrogen atoms collided into each other with enough force to stick together and form helium. Initially the hydrogen and helium existed as charged atoms, but after around 400 thousand years temperatures had cooled enough for them to capture electrons. The universe went from an opaque cloud of charged gas to a transparent but dark universe full of individual neutral hydrogen and helium atoms. The faint afterglow of the transition to transparency remains to this day as the cosmic microwave background radiation. Although now transparent, the universe was dark.



Collision of hydrogen atoms formed helium

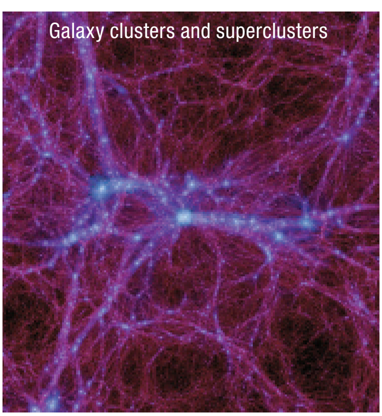


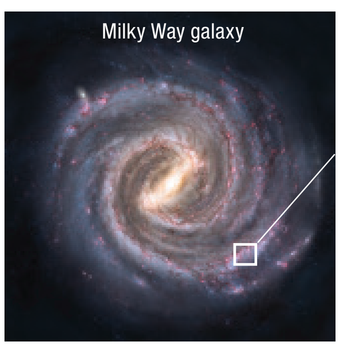
Andromeda, our closest galaxy

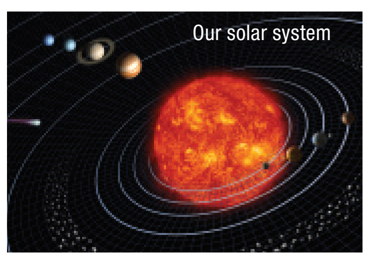
Fortunately the universe's dark ages didn't persist. If they had, the history of our universe would have been boring and bleak: an ever-bigger cold and dark space filled by individual hydrogen and helium atoms increasingly separate and alone in a lifeless universe. But the hydrogen and helium atoms shooting out into space didn't go solo for long. They came together in clumps thanks to variations in the density of energy and matter brought about by gravitational waves that had rippled through the big bang since the inflationary epoch. These clumps of hydrogen and helium atoms, along with mysterious dark matter and energy, are believed to have seeded galaxies. In those seed regions of relatively dense, focused pockets of matter, gravity started to pull the hydrogen and helium atoms closer together. The inward collapse of these atoms into many massive balls released enough heat to ignite the first stars. The first lights were switched on, ending the dark ages and shedding light on the mostly empty intervening space of our expanding universe.

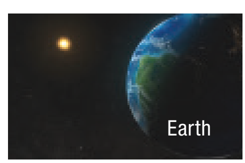
These first-generation stars formed within 400 million years after the big bang and were hundreds of times larger than our Sun. The gravity of these large stars attracted other stars and held them together as clusters of stars in what was the initial assembly of individual galaxies. Over the billions of years since, these galaxies have been pulled together, sometimes in spectacular intergalactic collisions, forming the intricate web-like structure of galaxy clusters and superclusters containing the 100 billion galaxies we can observe in our universe today. One of these galaxies would become our Milky Way and include our Sun – just one of 200 billion stars that swirl about the Milky Way's enormous central black hole.

Stars, like our Sun, are massive balls of burning gas. They burn so hot that hydrogen atoms collide with enough energy to stick together to make helium. In this fusing









Our place in a corner of the universe