

NEW

Story of the

# SOLAR SYSTEM

EXPLORE THE WONDERS OF OUR PLANETARY NEIGHBOURHOOD



Could we use the Sun to find a new Earth?

Digital Edition



FIRST EDITION

COMETS \* ASTEROIDS \* EXPLORATION & MORE

# Story of the SOLAR SYSTEM



## HOW IT FORMED

Discover the Nebular Hypothesis and how it explains the formation of the Sun, inner and outer planets, and other Solar System bodies



## WHAT IT CONTAINS

Explore the differences between terrestrial, giant and dwarf planets and how their behaviour affects each other and the space around them



## NEW DISCOVERIES

Find out about the incredible discoveries scientists are making in the outer Solar System thanks to probes, telescopes and mathematical modelling

**Your in-depth guide to the Sun, planets, and strange outer reaches of our local star system**



# Earth

## THE PERFECT PLANET

With all the ingredients to foster and sustain life, Earth is the miracle of the Solar System, but what is it that makes our home so special?

Written by  
PHILIP S KAY

**D**uring our busy daily routines, we rarely have time to step back and consider how lucky we are to be here. The chances of there being a planet like ours with the ideal circumstances and precise conditions to support intelligent life are so slim that it seems miraculous we exist to ponder anything at all. Earth is unique: it is the only celestial body we know of that hosts living entities. It is home to millions of species

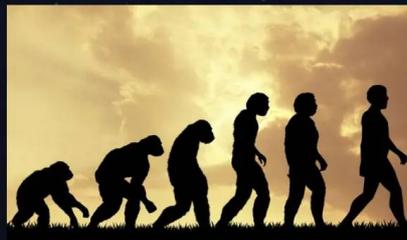
and such biodiversity that if there does turn out to be another planet with life on it – and if its inhabitants are advanced enough to visit us – they would surely marvel at the kaleidoscopic range of colour and astounding vibrancy on display. We often take our home for granted, but make no mistake, it is the most extraordinary place in the Solar System, and with a history that goes back over 4.5 billion years, it is almost as old.

Though experts still don't fully understand the early stages of our planet's history, they believe that its formation resulted from a tumultuous process that involved gravity pulling together large amounts of gas and dust particles until they coalesced into more substantial matter. After Earth's initial creation, several notable events heated, sculpted and shaped it over hundreds of millions of years. The first has come to be known as the 'Giant Impact Theory'. In his now widely accepted 1946 hypothesis, geologist Reginald



### LIFE AS WE KNOW IT

The process of evolution on our planet was extremely complex, and it took eons. Evidence of modern humans only dates back 300,000 years, despite simple single-celled organisms emerging almost 3.8 billion years earlier. Although rare extinction events affected the evolutionary timeline, intelligent life would never have developed at all without the unique combination of factors on Earth and its relative stability.





### WHAT IS AN OCEAN WORLD?

Oceans cover about 71 per cent of our homeworld. It is the only planet we know of that has the liquid surface water required for life. However, some moons in our Solar System, such as Europa, Ganymede and Callisto, may have oceans trapped beneath their icy surfaces that could hold even more water than Earth. That makes them ocean worlds, too.

GANYMEDE

EUROPA

CALLISTO



Daly proposed that the young Earth collided with another protoplanet (later called Theia), causing a massive ejection of matter that bound together to form our Moon. An occurrence of such magnitude would have generated enough heat on our planet to create a global ocean of molten magma.

Another key phase in Earth's development probably took place about 4 billion years ago and affected the whole Solar System. During a prolonged period referred to as the Late Heavy Bombardment, an enormous quantity of frozen asteroids and icy comets pounded Earth's surface. Although destructive, the projectiles may have delivered life-giving organic molecules and water, though some researchers contend that these already existed in the planet's original matter and were released as gases through volcanic activity. Either way, when the cosmic forces had finished forging their masterpiece, what remained was the largest and most complex terrestrial body in our Solar System. As the planet's temperatures fell, the processes of condensation and solidification

facilitated the formation of our oceans and landmasses, but it has only been within the last 200 million years that the continents we are so familiar with took up their current positions.

In total, billions of years passed before Earth's surface came to resemble the place we now call home, but what a home it is. From jungles, forests, mountains, plains and deserts to tundra, ice caps, oceans, rivers and lakes, our planet has it all. It offers a staggering variety of scenic showpieces across its continents – more than anyone could see in a lifetime. How is it possible for one planet to be so beautiful and alive while the others in our Solar System languish in the dead abyss of space? Well, several factors contribute to Earth's success, the first being location.

At an average distance of 93 million miles (150 million kilometres), our planet is far enough away from the Sun not to be a ferocious hothouse like Venus, yet still close enough to avoid the frozen fate of Mars. Earth sits in a narrow orbital band we call the continuously habitable zone,

**“Billions of years passed before Earth's surface resembled the place we now call home”**



where moderate temperatures allow liquid water to exist on its surface for long periods of time. The persistent presence of water is one of the most important elements in the emergence and development of life, and it is why much of our interplanetary exploration involves trying to find past or present evidence of it.

Like Mercury, Venus and Mars, Earth has a layered structure with a thin, solid crust surrounding a viscous mantle and a dense metallic core. However, it is the only one of those planets whose crust continually breaks apart and shifts. This phenomenon, known as active plate tectonics, relies on the lubricating properties of liquid water and happens because temperature fluctuations in the mantle cause convection currents to push and pull the giant pieces of rock that make up our planet's outer layer. The geological mechanism leads to earthquakes and volcanic eruptions, but it is also an essential component of Earth's long-lasting vitality, as it helps to recycle nutrients, balance our climate and release the energy that generates our protective magnetic field.

We all know how important the Sun is to life. It has been a symbol of birth and renewal for many civilisations, and it energises us with its comforting warmth as it rises over the morning horizon. Nevertheless, for planets without a strong magnetic field, it is a killer. Fortunately,



**ABOVE** Earth's active geology contributes to our planet's stability and safety

**LEFT** The presence of liquid water affects Earth's plate tectonics in a unique way

**BELOW** Earth's magnetosphere is the only effective one in the inner Solar System

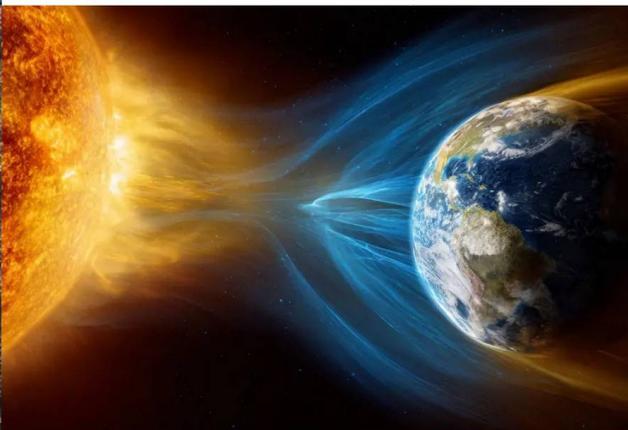
Earth's natural defensive barrier, called the magnetosphere, prevents most of its deadly solar particles and other deep-space rays from eroding our atmosphere by redirecting them. This feature, which is generated by the churning of Earth's liquid outer core, is critical for life, because without a thick enough atmosphere, there wouldn't be enough pressure to retain surface water. Our magnetosphere surrounds the whole globe and is the only effective one in the inner Solar System.

Safe beneath the embrace of our magnetic field, Earth's atmosphere was free to develop. Initially, it was made up of volatile gases like carbon dioxide, ammonia and methane – compounds that were released when our planet was repeatedly heated – but its composition changed. The instigators were tiny microbes called cyanobacteria that began producing oxygen more than 3 billion years ago through photosynthesis. It took a long time to accumulate in significant amounts, but as the planet matured, its atmosphere gradually attained the perfect balance of oxygen and nitrogen, a chemical cocktail conducive to additional life.

As well as providing the air we breathe, Earth's atmosphere benefits us in other ways: it acts as a shield, preventing most meteoroids and other space debris from impacting on the surface; it ensures that our world doesn't freeze over by trapping heat; its weather systems redistribute moisture across the globe; and its ozone layer stops us from becoming the victims of too much ultraviolet radiation.

In spite of everything that our magnetosphere and atmosphere do for our planet and its inhabitants, they can't save us from all the dangers that exist in our Solar System: rare space-weather events and Near-Earth Objects still pose a threat. Some of the Sun's eruptions can send massive solar storms speeding towards Earth. The huge amounts of high-energy particles they contain can overwhelm our magnetic field, causing damage to satellites, communications and other important infrastructure. More frightening, though, are asteroids and meteoroids that are too large or dense to disintegrate in the atmosphere. History tells us that when these make it through to hit the surface, they can be catastrophic enough to cause global devastation and wipe out entire species, like the dinosaurs.

Of course, the most immediate threat to Earth is humanity itself. With more than 8 billion of us now on the planet, we are depleting its natural resources, polluting its environment and changing its climate at an ever-increasing rate. The damage that we have caused is so extensive and serious that it has been a permanent topic of discussion over the last few decades. We already know that we need to take better care of our home, but if we think about how unlikely it is for a planet with such a unique combination of life-sustaining factors to exist in the first place and consider that it still took billions of years to nurture our species to fruition, we might be motivated to try harder.



# Mars

## THE RED PLANET

Beyond its silence and desolation, Mars hides secrets that hint at a very different and dynamic past

Written by  
PHILIP S KAY

Mars has captivated stargazers for centuries. Its iconic red ochre surface, mysterious shifting sands and intriguing topological features fired the imagination of early astronomers and inspired wondrous tales of advanced alien civilisations. These days, with decades of solid scientific research to rely on, we are piecing together the true story of our fascinating neighbour to reveal some amazing things. Mars' story concerns more than just its own history, though. It is an interplanetary tale, interwoven with the yarn of humanity's incredible efforts to explore and learn about its dusty, barren wastes.

Mars has some things in common with our homeworld: it is a terrestrial planet, comprising a metallic core, silicate-rich mantle and solid crust, and the 24.65 hours it takes to complete a full rotation on its axis makes Martian days (called sols) of similar length to Earth's. The Red Planet also has seasons, but they are longer and less evenly distributed than ours because Mars spends almost twice as long travelling around the sun (687 Earth days) on a more elliptical orbital path. Other fundamental differences between the

planets include size and temperature: Mars is only about half as big as Earth and much colder, with its lows plummeting to a frigid -153C (-225F). Due to their differing orbits and speeds, the distance between Earth and Mars is always fluctuating, but it averages approximately 140 million miles (225 million km). By current estimations, it would take humans between six and nine months to travel there.

That might be possible in the not-too-distant future, but until now, we have depended on unmanned missions to collect the wealth of information we know about Mars. Since the NASA spacecraft Mariner 4 made the first successful flyby of the planet in July 1965, space agencies have sent an assortment of orbiters, landers and rovers to the Red Planet to find out more about it. Equipped with sophisticated sensing equipment, an impressive array of instruments and state-of-the-art image-capturing technology, they have been able to fill in many of the gaps in our knowledge. Their data has helped paint a picture of a planet with formidable features, brutal environmental conditions and surprising geological characteristics.

In 1971, when Mariner 9 reached Mars, it set a new benchmark for space exploration by being the first craft to orbit another planet. It charted 85 per cent of Mars' surface and transmitted thousands of images back to NASA technicians. What Mariner 9 captured was astounding: a world defined by vast plains and massive plateaus – one pockmarked with enormous volcanoes, immense impact craters, and riven by deep canyons, lava tubes and other channels. The orbiter's images even showed Mars' two small, irregularly shaped moons, Phobos and Deimos.



**LEFT** Mars has polar ice caps. The southern cap is covered with a permanent layer of frozen carbon dioxide



## THE INNER PLANETS

As the number of missions to Mars increased, it became evident that the Red Planet is much more interesting than we once thought. It is home to our Solar System's tallest mountain (Olympus Mons), its longest canyon system (Valles Marineris) and one of its largest impact basins (Hellas Planitia). Now, NASA's Mars Reconnaissance Orbiter enables us to see these and other areas in staggering detail through its powerful HiRISE (High Resolution Imaging Science Experiment) camera. The clarity of HiRISE's images seems to put Mars' surface within arm's reach of viewers, but to understand more about the planet, we also needed to land there and investigate from the ground.

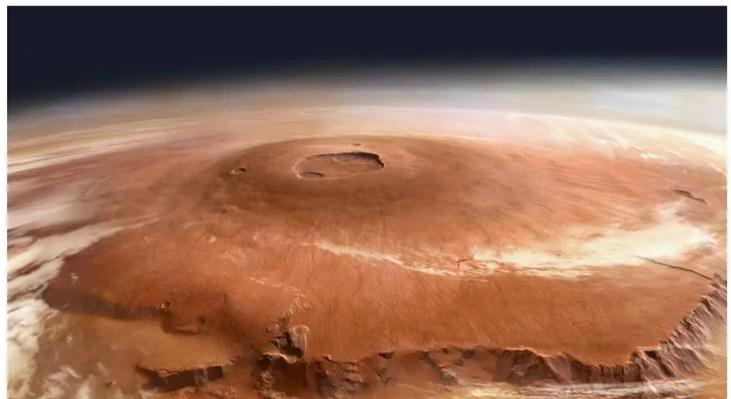
Unfortunately, with its low gravity (38 per cent of Earth's), carbon dioxide-dominated atmosphere, hazardous radiation and fierce dust storms – which sometimes cover the whole planet – Mars' inhospitable environment makes it extremely difficult for human habitation. That's where the deployment of a small armada of robotic vehicles has proved invaluable. Starting with NASA's Mars Pathfinder mission in 1997, rovers have been scouring the Red Planet to gather data and undertake various investigative tasks that would be impossible for us. Although other vehicles, called landers, had touched down on the Martian surface earlier, they were stationary and limited to collecting samples in situ. The mobility of mechanical rovers was a game-changing development in the exploration of Mars, as it boosted our knowledge at a much faster rate.

In addition to taking excellent photographs of the Martian surface, rovers can study its rocks and regolith (broken rock, soil deposits and the iron oxide dust that gives Mars its red colour). Upon landing in 2004, the NASA rovers Spirit and Opportunity set out on a mission that would result in a remarkable discovery. They found



### **OLYMPUS MONS: A VOLCANIC GIANT**

Topping out at around 22,000 metres (72,000 feet), the biggest mountain in the Solar System is almost three times taller than Mount Everest. The gigantic shield volcano, whose base area would cover most of France, is so huge that it pokes out of Mars' thin atmosphere and into space, despite its slopes only having a leisurely five per cent average gradient.



## MISSIONS TO MARS

Mars is the most explored planet beyond Earth, having been the target destination of more than 50 missions. A success rate of about 50 per cent highlights the difficult nature of the task. The United States' NASA has led the way, but other space agencies in Russia, Europe, India, the United Arab Emirates and China have all sent spacecraft to the Red Planet.



**LEFT** The Martian surface is explored by NASA rovers searching for signs of life

**BELOW** Mars' rocks provide clues to the Red Planet's distant and watery past

Not all of the water on Mars disappeared, however; some remains frozen at the planet's poles, while more exists beneath the surface, safe from the Solar System's cosmic onslaught. Both of Mars' polar regions are covered with thick ice caps that consist of water ice and frozen carbon dioxide. Although they shrink and expand throughout the Martian year, owing to seasonal variations, they are permanent fixtures. Data from seismic studies conducted in the Elysium Planitia region by NASA's InSight Lander has shown that water lies trapped in the cracks of porous rocks deep underground. Some experts believe that in all its forms, there is still enough water locked away on Mars to submerge the whole planet.

The realisation that ancient Mars was once awash with flowing water has provided scientists with extra impetus to find the answers to our biggest questions. Could life have existed on the Red Planet? Does it exist there now, hidden out of reach? We don't know, but the discovery of water increases the possibility, and the search continues in earnest. NASA's current operational rovers, Curiosity and Perseverance, are playing their part by investigating a pair of promising craters. Curiosity is examining whether past environmental conditions were conducive to microbial life, while Perseverance looks for indicators of biological origin called biosignatures. Like robotic archaeologists, they dig and collect samples to establish whether Mars was once habitable. How long will it be until they uncover something that changes our perception of the Solar System?

Despite all we have learnt, the full story of the Red Planet has yet to be told. It remains a mystery – one that has benefited from the previous limitations of our technology and the silent void of space that separates it from Earth. Today, though, the creations of some of our brightest minds venture forth undeterred. The geological echoes of the past they have recovered from Mars' irradiated regolith so far have given us tantalising glimpses into the planet's history and development. Such exciting breakthroughs can only embolden our ambition and steel our resolve to keep on exploring. And who knows, through further study, we may learn enough to help ensure that our home doesn't end up as dead and desolate as our Martian neighbour, or even how we might survive there ourselves some day.



types of rocks and minerals with compositions that only form in watery environments, providing conclusive proof that the Red Planet's desert landscape was once wet. Together with mapping and mineral distribution data collated from orbiters, the rovers' ground-based work revealed that ancient Mars used to have river systems, lakes and perhaps even a huge ocean. Four billion years ago, the Red Planet was a very different place. So what happened?

As with Earth, the churning of Mars' superheated core used to produce a protective

magnetic field around the planet, shielding it from the deadly effects of solar winds and radiation. This magnetosphere prevented Mars' atmosphere, which was much thicker and denser than it is now, from being stripped into space. It also ensured that there was enough atmospheric pressure for a large quantity of liquid water to exist on the surface. Sadly for Mars, the planet's core cooled faster than ours; it eventually lost its heat and the ability to maintain its magnetosphere. It could therefore no longer hold on to its thick atmosphere or surface water, which evaporated.