1

why mars matters

Are we alone in the universe? Earth might be an oasis of life, the only place in the universe where living beings of any kind exist. On the other hand, life might be as common across the universe as the hundreds of billions of stars and planets that populate it. If life is common, if the genesis of life is fairly easy given the right environment and the necessary elemental materials, some form of life might exist right next door, on Mars, and if life were discovered on Mars that is of an independent origin than life on Earth, we could safely predict that life is common throughout the universe. Such a discovery would be extraordinary. Mars Matters.

Mars has always attracted the attention of sky watchers on Earth, whether as the Greek (Ares) or Roman (Mars) or Babylonian (Nirgal) or Hindu (Mangala or Angaraka) God of War, or as the Chinese (Huo Hsing) or Japanese (Kasei) Fire star. The Incas named this planet Auqakuh; in ancient Sumer, it was called Simud; in ancient Hebrew, Ma'adim. Everywhere and for all of remembered history, Mars always had a name. We have been watching it for as long as we've been looking up into the heavens. As a planet (a wandering star, in the vernacular of the ancient Greeks), Mars stood out as a special object in the sky, comparable in brightness only to Venus, Jupiter, and Saturn, but even without a telescope, Mars is more colorful in the nighttime sky than the other planets, appearing red in color much of the time. Perhaps that is the lure of Mars. Perhaps the appeal of Mars in an ancient sky full of gods, in a celestial tapestry of myths, led us to imagine Mars as a place more special than all the other places we might visit in our imaginations.

We have been attracted to the idea of life on Mars for a very long time, by turns led and misled by our desires and imaginations. Thousands of years of human history, in which humans across all cultures invested the bright red planet with enormous mythological importance, combined with the medieval and Renaissance-era expectation that almost all other worlds should be inhabited, may have led astronomers to expect to find that Mars was Earthlike, and so they may have found what they wanted to find. The picture of Mars that emerged after the invention of the telescope revealed that the fourth planet from the Sun shares many life-critical similarities with Earth. With that realization, it was natural for astronomers to draw the conclusion that Mars must also be capable of hosting living things. As we approach a time when we might colonize Mars, we need to understand the burden of historical expectations regarding life on Mars that we all shoulder, because the history of discoveries about Mars made over the last four hundred years motivates today's scientists as they explore and study the red planet.

Does life exist on Mars? Maybe. Are the Martians Little Green Men? Not likely. Could primitive microorganisms survive on Mars, living in subsurface reservoirs of liquid water? Yes. Long ago, could spores have been transferred via a large impact event from Mars to Earth or from Earth to Mars? Very possibly.

We know that the six most important elemental building blocks of life—carbon, oxygen, nitrogen, hydrogen, phosphorous, and sulfur—exist virtually everywhere in the universe. The backbone of chemical life as we know it is carbon, which is abundant on Mars. Mars also has plenty of nitrogen and phosphorous, which are necessary components of both amino acids and DNA. We know Mars has water, which is made of hydrogen and oxygen, so those two elements, both together as water and separately for other chemical processes, are readily available. Sulfur, which occurs in all sugars, proteins, and nucleic acids, is also abundant on Mars. Chemically, at least, Mars has all the right stuff for the origin and survival of chemically based life. In addition, Mars has spent part of the last 4.5 billion years since the birth of the Sun in the Goldilocks zone of our solar system, where temperatures, pressures, and densities are just right to allow liquid water to exist on or just below the Martian surface for at least part of Mars's annual cycle of seasons.

In principle, Mars could therefore harbor life, whether as a birthplace for living things or as a nurturing environment for life-forms that might have been deposited there. Furthermore, Mars may be a model for helping us understand the likelihood that life could exist on any of the many exoplanets recently discovered by astronomers that lie in the Goldilocks zones around their host stars.

Some scientists have speculated that life in our own solar system may have started on Mars and later been accidentally exported to Earth when a large asteroid collided with Mars and splashed Martian rocks into space. Alternatively, though dynamically more difficult, life may have started on Earth and, as the result of a large terrestrial impact event, been transported to Mars, in which case Mars could function as a nurturing environment for life-forms that might have been deposited there after forming elsewhere.

Earth and Mars formed at about the same time, almost 4.5 billion years ago, in a swirling disk of gas and dust that orbited the newborn Sun. After suffering through the traumatic early stages of formation, in which large asteroids and myriad comets likely continually crashed into their surfaces for several hundred million years, the solar system stabilized. As soon as the planets cooled enough for solid land to begin to form, both Earth and Mars almost certainly also had liquid water pooling on their surfaces.

On at least one of these two planets, life made an appearance fairly soon after these primordial formation events. Australian geologist Allen Nutman and his scientific team recently pushed the time for the oldest known living things on Earth all the way back to 3.7 billion years ago. In a rock formation in Isua, Greenland, they found layered structures that prove that the rock itself is a stromatolite.[1] Such rocks form as colonies of microorganisms deposit layers of minerals as they grow. From Nutman's work, we therefore know that stromatolites thrived in shallow seas on Earth when our planet was only 800 million years old. Incredibly, life must have taken root on Earth very quickly after it formed. Equally certainly, Mars was also

Figure 1.1. Living marine stromatolites in Hamlin Pool, Australia. See Plate 1. Image courtesy of Kristina D. C. Hoepper/Creative Commons at https://www.flickr.com/photos/4nitsirk/11902636365

warm and wet when it too was only 800 million years old. If so, then life could have formed or grabbed hold on Mars at about the same time. Thus, the existence of stromatolites on a young Earth strongly suggests that a young Mars, too, could have had colonies of primitive living things in its shallow lakes.

Without question, Mars is the closest place in the universe where we plausibly might find extraterrestrial life. For centuries, astronomers repeatedly have claimed to have discovered evidence suggesting Mars harbors life; however, to date all of these findings have either been disproven or become highly disputed. Where does this leave us? Today, we lack anything resembling a scientific consensus regarding how to answer the question, “Does or did life exist on Mars?” The existence of so many varied and controversial claims for life on Mars suggests the tantalizing possibility that life once thrived there or even exists on Mars today; yet, we cannot point to any one piece of unassailable evidence for once or current life on Mars. The jury is still out; it needs more evidence.

The discovery of extraterrestrial life on Mars would rank among the most profound and important discoveries ever made in the history of science. Such a discovery would also raise enormous ethical and moral concerns. If scientists conclude that life exists on Mars, then the debate as to whether we should colonize Mars, knowing that it is already inhabited, could become one of the most important questions facing us in the mid-twenty-first century. Does humanity have an inalienable right to potentially disrupt life on another world simply because we have the technological ability to transport members of our species across interplanetary space? Some ethicists would argue that if Mars is home to nothing more biologically advanced than a few colonies of microbes, we should feel free to colonize the red planet, while if we found multi-celled creatures, we should leave them alone.

How soon might humans set foot on Mars? As instructed by the NASA Authorization Act of 2010 and the U.S. National Space Policy, also issued in 2010, NASA is developing the capabilities for sending humans to Mars and returning them safely to Earth by the 2030s. The time frame for reaching Mars in these plans is likely overly optimistic, and NASA is gradually scaling back expectations; nevertheless, we are planning to send astronauts to Mars within the lifetimes of many of us. Current plans include a first phase of exploration in the vicinity of the Moon, including building a spaceport in lunar orbit, which would be NASA's gateway to deep space—that being targets well beyond the Moon.

NASA's human missions to Mars (and the Moon) will be launched from the Kennedy Space Center in Florida, where an advanced tracking system designed to support the goal of sending humans beyond the Moon is already nearing completion. The Space Launch System (SLS), if completed, will be about 20 percent more powerful than the Saturn V rocket that supported the Apollo program for exploration of the Moon (the Saturn V could lift 135 tons into orbit) and will be built using the same, time-tested rocket technology developed for the Space Shuttle program.

The tremendous power of the SLS may eventually send astronauts to Mars in the Orion Multi-Purpose Crew Vehicle. The Orion would provide living space for the astronauts during the 16-month-long round-trip journey to Mars. The first SLS vehicle, known as Block 1, which has a completion goal of 2018, will have a lift capability of 77 tons. The plan for the first SLS mission is to launch a spacecraft to an orbit past the Moon and then return that vehicle to Earth. The next design phase of SLS, Block 1B, is intended to add a more powerful upper stage, giving SLS a planned lift capability of 115 tons. NASA intends to use this configuration to send astronauts well beyond the Moon, perhaps to the vicinity of a near-Earth asteroid. The third design phase of SLS, Block 2, includes plans to replace the five rocket boosters on Block 1 with solid or liquid propellant boosters that, in design, are intended to have a 143-ton lift capability. Current estimates of the planned final configuration of the SLS that will launch astronauts to Mars are that this vehicle will weigh 6.5 million pounds, comparable to 10 fully loaded 747 jets; provide 9.2 million pounds of thrust at liftoff, equivalent to more than 208,000 Corvette engines; and stand 365 feet high, taller than a thirty-story building.

The first, unmanned, two-orbit test flight of Orion was carried out in December 2014. The first integrated launch and flight of the SLS rocket and the Orion spacecraft to a point beyond the Moon, known as Exploration Mission–1, is now scheduled, without an astronaut crew, for 2019.[2] The first crewed flight of astronauts on Orion, Exploration Mission–2, was scheduled for 2021, but likely will be delayed. The second phase of exploration, which includes plans for an eventual trip to Mars, will begin in the late 2020s with a planned one-year crewed mission to the lunar spaceport. By the 2030s, NASA intends to have tested all the systems and capabilities of Orion necessary to carry astronauts and life-critical cargo to Mars's orbit and then return them to Earth.

Sending astronauts to Mars, landing them on the surface, keeping them alive, and then lifting them back off the Martian surface and returning them safely home remain well beyond NASA's current capabilities. The downward pull of gravity at the surface of Mars is almost 2.5 times greater than the pull of gravity at the surface of the Moon. As a result, safely landing astronauts on Mars requires retrorockets or using some other lander design that will slow the downward acceleration of astronauts toward the surface of Mars. For the same reason, blasting back off of Mars will be a much greater technological challenge than was returning astronauts from the surface of the Moon. Getting to and from Mars, of course, is only part of the problem of living on Mars, and NASA is already working on imaginative plans for building a Mars colony.

NASA, however, is no longer the only player in the exploration of space and the race to Mars. PayPal founder and entrepreneur Elon Musk made clear, when he founded his SpaceX corporation in 2002, that his goal was to establish a human colony on Mars. Already, SpaceX has successfully delivered cargo to the Space Station in its Dragon spacecraft, which one day is intended to ferry astronauts to the Space Station and then carry them farther into space. SpaceX's current rocket, the two-stage Falcon 9, has the thrust of five 747s at full power and can lift 28 tons into orbit. In December 2015, SpaceX successfully demonstrated that the first stage can be safely landed back on Earth for reuse, and in May 2017, reused a first stage in a second rocket launch for the first time. SpaceX is now working toward the launch of the much more powerful Falcon Heavy, which is supposed to be capable of lifting 55 tons into orbit.

In June 2016, in an interview with the *Washington Post*, Musk first offered hints about his audacious plans for sending his first unmanned flight to Mars in 2018. Then in September 2016, he explained those plans in more detail at the International Astronautical Congress (IAC) in Guadalajara, Mexico. Two years later, he updated those plans in a presentation to the IAC in Adelaide, Australia, where he discussed making the human race "a multiplanet species." Musk's planned launch vehicle, which has had several names, including the Interplanetary Transport System (ITS) and the BFR ("B" for "big" and "R" for "rocket"), will be powered by thirty-one Raptor rocket engines, with a liftoff thrust of 5,400 tons (almost 11 million pounds), capable of lifting 150 tons into orbit. The BFR will replace all the previous SpaceX rockets and spacecraft (Falcon 9, Falcon Heavy, Dragon). According to current plans, the Raptors, which are still in the design phase by SpaceX, will use carbon-fiber tanks holding (separately) liquid methane and liquid oxygen as fuel and will be able to refuel in space, which would enable the BFR to then take all 150 lifted tons all the way to Mars. In 2022, Musk intends to use two ITS launches to send to and land two cargo payloads on Mars in Dragon spacecraft. If successive launches follow the company's extremely aggressive (many would say unrealistic) time line, SpaceX intends to launch four rockets to Mars in 2024; two would ferry additional cargo and two would carry human crews with up to one hundred adventurers in each, who would arrive at and land on Mars, establish a colony, construct a propellant production depot, and find a supply of water. Sci-fi fans might note the similarity of Musk's plans to those described in Kim Stanley Robinson's 1990s award-winning trilogy *Red Mars*, *Green Mars*, and *Blue Mars*, in which the First Hundred colonists were launched to the red planet in 2026.

Over the next forty years, Musk wants to shuttle as many as a million colonists to Mars and to begin manipulating the Martian climate to make it more like that of Earth, a concept referred to as terraforming. He claims that his Martians will be able to sustain themselves on Mars and also come home again, as his rockets will make regular roundtrips from Earth to Mars and back again. The assumption that colonists will ever get back to Earth, however, depends first on their ability to survive the harsh radiation environment of space and on the surface of Mars, and then on the ability of SpaceX to use solar power to manufacture methane and oxygen fuels on Mars (from subsurface and atmospheric reservoirs of water and carbon dioxide) for return trips. Musk's audacious plans also may require an infusion of tens to hundreds of billions of dollars for development, which is beyond his personal ability to fund.

Another tech billionaire, Amazon founder Jeffrey Bezos, is also building rockets through his venture Blue Origin and has his own plans for sending colonists to Mars. In 2016, Blue Origin successfully launched and landed its first rocket, the New Shepard, named after the United States' first astronaut Alan Shepard, on a suborbital flight. Blue Origin also is developing a more powerful rocket called New Glenn, named for the United States' first astronaut to orbit Earth, John Glenn, which it intends to launch from a massive facility it has under construction at the Kennedy Space Center's Exploration Park at Cape Canaveral, Florida. Plans for New Glenn, which may debut in 2020, include a reusable first-stage rocket as part of a three-stage, 350-foot-tall launch vehicle that will burn liquid hydrogen and liquid oxygen. Bezos expects his project to take many decades, rather than a single decade. First, Bezos expects his Blue Origin rockets to launch satellites and cargo, with a goal of delivering the equipment to the Moon that would be necessary to support a human colony there. Then he intends to place millions of humans into space, where they will work in near-Earth orbit. Only then will he set his sights on placing colonists on both the Moon and Mars. According to Bezos, "I think that if you go to the Moon first, and make the Moon your home, then you can get to Mars more easily."[3]

NASA may also have additional competition from a private Dutch group, Mars One.[4] Founded in 2011 by Bas Lansdorp and Arno Wielders, Mars One intends to launch an unmanned mission to Mars in 2020, a first crew to Mars in 2031, and send a second crew in 2033. Mars One began astronaut selections in 2013 and intends to select their first crews in 2017, at which time they will begin training for their one-way trip to Mars. In contrast to NASA, SpaceX, and Blue Origin, Mars One is not designing or manufacturing rockets, launch systems, landing modules, life support units, or rovers. Instead, they intend to purchase everything they need from established aerospace companies. Whether Mars One can actually buy the mission hardware they need remains to be seen.

One other player has recently announced plans for colonizing Mars. In February 2017, at the World Government Summit in Dubai, Sheikh Mohammed bin Rashid Al Maktoum, ruler of Dubai and vice president of the United Arab Emirates, announced that the UAE planned to build a city on Mars within one hundred years.[5] The UAE's Mars 2117 Project is only a concept for now; however, the UAE created its own space agency in 2014 and has plans to send an unmanned probe to Mars by 2021, coinciding with the fiftieth anniversary of the UAE gaining political independence from Great Britain in 1971.[6]

The reason so many of us are so interested in Mars is that life on Mars is possible, whether for us in the future or for native Martians. What if Mars harbors life today? What if astronauts establish a human colony on Mars in the twenty-first century? Will we bring death and destruction to Mars, as the first European colonists did to the New World, when they brought smallpox, measles, whooping cough, bubonic plague, and dysentery to a world that lacked the ability to fend off those attackers? They also brought horses and pigs that often outcompeted indigenous wildlife species for survival. Together, the Old World diseases and animals wreaked havoc on the biota of the New World. Humanity also does not have a good track record in taking care of remote wilderness areas. The ecosystems of the Arctic, Antarctic, and Amazon are all threatened by the encroachment of human civilization, by hunting and by global warming. If we cannot find the collective will to help the polar bears, penguins, and giant otters survive on our own planet, will we do anything to help ensure the survival of microscopic Martians?

Do microscopic Martians even matter? Yes. A second genesis, life that began completely independently of terrestrial origins, might have occurred there. Even if life on Mars is limited to bacterial-sized beings, buried underground or hiding deep in a crevice where they are protected from dangerous ultraviolet radiation and cosmic rays and where they can find water, those microscopic Martians would be astoundingly important to our understanding of life in the universe. Life on Mars that is independent of life on Earth would send us a clear message about exobiology: life happens anywhere and everywhere that conditions allow. Alternatively, if we find microscopic life that is DNA-based, we also receive an enormously important message about exobiology and clues about our distant, evolutionary past: life is easily transported across interplanetary space. Once life gets started, it spreads, and thus, whether we are Martians or the Martians are us, we're all related. Finally, if we find that Mars is barren and sterile, without even microscopic Martians, we will know that we are more alone in the solar system and perhaps in the galaxy and universe than many of us currently assume. Whatever the answer, the answer matters. Mars matters.

As the possibility of travel to Mars draws closer, we have an urgent scientific imperative to determine whether life exists on our planetary neighbor. Putting astronauts into Mars's orbit creates very little risk for contaminating Mars. Landing habitat modules and astronauts on Mars and attempting to build a colony on Mars, however, could inadvertently destroy any life that might exist on Mars before we have a chance to fully explore the red planet and discover whether life exists there.

The scientific detective story that follows traces the many attempts to identify life on Mars from the seventeenth century until now. As we consider these claims and discoveries, we might think about whether some caution is in order before we begin to colonize Mars. Perhaps our decision as to whether to colonize Mars should not be left strictly to politicians, professional astronauts and astronomers, space enthusiasts, and deep-pocketed venture capitalists. We all should better understand Mars, and we all should participate in this public debate.