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## Review Article

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# Seeding the Solar System with Life: Mars, Venus, Earth, Moon, Protoplanets

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**Abstract:** In the space of the entire universe, the only conclusive evidence of life, is found on Earth. Although the ultimate source of all life is unknown, many investigators believe Earth, Mars, and Venus may have been seeded with life when these planets, and the sun, were forming in a galactic cluster of thousands of stars and protoplanets. Yet others hypothesize that while and after becoming established members of this solar system, these worlds became contaminated with life during the heavy bombardment phase when struck by millions of life-bearing meteors, asteroids, comets and oceans of ice. Because bolide impacts may eject tons of life-bearing debris into space, and as powerful solar winds may blow upper atmospheric organisms into space, these three planets may have repeatedly exchanged living organisms for billions of years. In support of these hypotheses is evidence *suggestive* of stromatolites, algae, and lichens on Mars, fungi on Mars and Venus, and formations *resembling* fossilized acritarchs and metazoans on Mars, and fossilized impressions *resembling* microbial organisms on the lunar surface, and dormant microbes recovered from the interior of a lunar camera. The evidence reviewed in this report supports the interplanetary transfer hypothesis and that Earth may be seeding this solar system with life.

**Keywords:** Mars; Venus; Earth; Moon; Meteors; ALH 84001; Algae; Cyanobacteria; Fungi; Lichens; Stromatolites; Metazoans; Fossils; Interplanetary transfer of life; lithopanspermia; Planetary nebulae

## 1 Seeding the Solar System with Life: Protoplanets, Mars, Venus, Earth, Moon

How and when life began, is unknown. Sir Fred Hoyle (1982) Nobel laureates Svante Arrhenius (1908), Francis Crick (1981), Harold Urey (Arnold *et al.* 1995; Urey 1962, 1966), and other investigators, have theorized that life is widespread in this universe and was delivered to Earth via solar winds, meteors, asteroids, and comets from older planets in distant solar systems (Hoyle and Wickramasinghe 2000; Joseph 2009; Joseph and Schild 2010a; Valtonen *et al.* 2008). Yet others have proposed that proto-

planets, including Earth, were seeded with life when these worlds first formed in a galactic cluster within a nebular cloud amongst thousands of other new born stars (Adams and Spergel 2005; Fragkou *et al.* 2019; Johansen and Lambrechts 2017; Jones *et al.* 2019). Therefore, according to this scenario, as worlds were formed and destroyed (Boyle and Redman 2016; Stephan *et al.* 2020) life within this cosmic debris may have spread between these protoplanets (Adams and Spergel 2005; Gibson *et al.* 2011; Joseph 2009; Joseph and Schild 2010b; Valtonen *et al.* 2008) and what would become Mars, Venus, Earth and its moon, may have become infested with life before this solar system was established. It has also been hypothesized that life may have been repeatedly transferred between these worlds during the heavy bombardment phase of this solar system's stabilization (Gladman *et al.* 1996, 2005; Mileikowsky *et al.* 2000a,b) and intermittently thereafter (Beech *et al.* 2018; Joseph 2009; Joseph and Schild 2010a; Schulze-Makuch *et al.* 2005) via powerful solar winds and life-infested bolides ejected into space that later crash upon the surface of these worlds.

In support of all these theories and scenarios, is evidence—but no proof—that between 4.2 to 3.7 bya, during the heavy bombardment phase, life may have taken

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root on Mars (Clement *et al.* 1998; Noffke 2015; Thomas-Keprta *et al.* 2009) and Earth (Nemchin *et al.* 2008; Nutman *et al.* 2016; O'Neil *et al.* 2008; Rosing and Frei 2004); and then, over the ensuing billions of years, the inner planets were repeatedly intermittently seeded with life (Beech *et al.* 2018; Joseph 2019). Moreover, Earth may have been seeding the inner planets when tons of rock and soil—and adhering organisms—were ejected into space via powerful solar winds (Joseph 2009) and following impacts by comets, asteroids and meteors (Beech *et al.* 2018; Gladman *et al.* 2005; Joseph 2000; Mileikowsky *et al.* 2000a,b).

If life was delivered via debris from outside this solar system, and/or if impacts on Earth also caused the dispersal of life, this may explain why specimens *similar to* terrestrial fungi have been observed on Mars (Joseph *et al.* 2019, 2020a) and Venus (Joseph 2019; Ksanfomality 2013). This would also account for why specimens *resembling* algae, lichens, stromatolites, and fossilized algae and metazoans have been observed on Mars (Joseph and Armstrong 2020; Joseph *et al.* 2019, 2020a,b; Kaźmierczak 2016, 2020; Noffke 2015; Rabb 2018; Rizzo 2020; Rizzo and Cantasano 2009, 2017; Ruff and Farmer 2016). The interplanetary transfer of life would also explain why fossilized impressions resembling "nanobacteria," terrestrial bacteria and micro-Ediacarans, have been respectively identified in a lunar meteorite (Sears and Kral 1998) and lunar soil samples (Joseph and Schild 2010a; Zhmur and Gerasimenko 1999); and why dormant spores were found within a lunar camera that had been sitting on the moon for three years (Mitchell and Ellis 1971).

Nevertheless, it must be stressed that there is no conclusive proof of current or past life on any planet other than Earth. As the definitive evidence of life exists only on Earth, it is also reasonable to hypothesize that after this solar system was formed, Earth may have repeatedly seeded neighboring planets and moons with life; the ultimate source of which, is unknown.

## 2 Genetics and the Improbable Origins of Life

Be it in the ancient past or following the classic experiments of Miller and Urey (1959a,b) all attempts to fashion life from non-life have failed. There are published estimates that it would have taken 100 billion to trillions of years to fashion the nucleotides that comprise a single macromolecule of DNA (Crick 1981; Dose 1988; Horgan 1991; Hoyle 1982; Joseph and Schild 2010a; Kuppers 1990; Yockey 1977). Further, once that first DNA molecule had been created,

and based on complex genetic statistical analyses, it could have taken from 10 to 13 billion years for that first gene to undergo sufficient duplicate and recombination events to fashion a minimal genome capable of maintaining the life of the simplest organism on Earth (Anisimov 2010; Jose *et al.* 2010; Joseph and Wickramasinghe 2011; Sharov 2010). Carsonella, for example, maintains the smallest genome of all living organisms: 160,000 base-pairs of DNA, and 182 separate genes (Nakabachi *et al.* 2006); and thus this can be considered the minimal number of genes necessary to sustain life. However, Carsonella is parasitic and depends on a living host, a psyllid insect, to survive. By contrast, the genome of *Mycoplasma genitalium* (Fraser *et al.* 1995), the smallest free-living microbe, has over 580,000 base pairs and over 213 genes, 182 of these coding for proteins; and beginning with the first gene, it would have taken up to 13 billion years of recombination and duplicative events to fashion a minimal life-sustaining genome (Joseph and Wickramasinghe 2011). Estimates are that Earth is only 4.6 billion years in age (Lugmair and Shukolyukov 2001). Therefore, the first minimal gene set sufficient to sustain life, was formed at least 6 billion years before Earth and this solar system were established. The establishment of DNA, however, is just the one step in fashioning a single living organism.

Single cellular microbes are comprised of more than 2,500 small molecules, nuclei acids and amino acids consisting of 10 to 50 tightly packed atoms, and macromolecules and polymeric molecules which precisely interact as a cohesive whole and function together as a living mosaic of tissues (Cowan and Talaro 2008; Joseph and Schild 2010a). The thousands of different molecules that comprise a single cellular creature perform an incredible variety of chemical reactions in concert with that cell's protein (enzyme) products; whereas the smallest of single celled creatures consists of and requires over 700 proteins (Cowan and Talaro 2008).

Yockey (1977) calculated that the probability of achieving the linear structure of one protein 104 amino acids long, by chance, is  $2 \times 10^{-65}$ . The probability of forming just a single protein consisting of a chain of 300 amino acids is  $(1/20)^{300}$ , or 1 chance in  $2.04 \times 10^{390}$  (Hoyle 1982). The probability of creating 700 proteins—the number necessary to fashion a living mosaic of tissues—might be in excess of  $700 \times 10^{-6500}$  (Joseph and Schild 2010a,b). According to "Borel's Law" any odds beyond 1 in  $10^{50}$  have a zero probability of ever happening: "phenomena with very small probabilities do not occur" (Borel 1962).

As argued by Dose (1988), it appears nearly impossible for a single cell to have been fashioned by chance or on Earth. "The difficulties that must be overcome are at

present beyond our imagination." The chairman of a National Academy of Sciences committee which investigated the evidence, Dr. Harold Klein, concluded it is impossible to determine how even the simplest bacterium could have been created (Horgan 1991). As summed up by Koppers (1990): "The expectation probability for the nucleotide sequence of a bacterium is thus so slight that not even the entire space of the universe would be enough to make the random synthesis of a bacterial genome probable."

The logical conclusion is that life, and the genes necessary to maintain life, must have originated on planets much older than our own.

### 3 Galactic Clusters, Protoplanets, Solar Systems, and Interplanetary Transfer of Life

It is completely improbable that life was fashioned and originated on this planet or in this solar system (Crick 1981; Dose 1988; Hoyle 1982; Yockey 1977) as there was not enough time and all the constituent elements for the manufacture of DNA were missing. It would take over 10 billion years to fashion a complete life-sustaining genome from a single gene; and this solar system is believed to have formed at least 4.570 Ga when the necessary materials and elements in the solar nebula began to condense (Lugmair and Shukolyukov 2001). However, if we accept, as a hypothetical, that life was created somewhere in this galaxy—which has been estimated to be 13 billion years in age (Pace and Pasquini 2004; Pasquini *et al.* 2004)—and/or that the conditions of nebular clouds somehow fortuitously produce DNA-equipped living organisms (Joseph and Schild 2010a,b), then it can be predicted that once life began to replicate, diversify, and evolve, that living organisms were dispersed to other planets and solar systems in this galaxy, and infected protoplanets being fashioned in those nebular clouds.

Quantitative studies estimate that about one third of the debris circulating in space between planets will be ejected from solar systems with Jupiter-sized worlds (Melosh 2003). Given that some of that some of this debris is ejected from an impacted surface following meteor strikes, if that debris contains living matter then, hypothetically, one solar system might seed another; so long as living organisms or their spores are safely embedded deep within the matrix of a large meteor, asteroid or comet that is at least (>10 kg), thereby providing a thick shielding against

UV and cosmic rays (Belbruno *et al.* 2012; Horneck 1993; Nicholson *et al.* 2000).

However, it's been argued that there is a very low probability that life can be transferred between solar systems due to the distance, time, low interstellar density, and because solar systems are in motion (Melosh 2003). As estimated by Melosh (2003) of all the meteorites that are ejected from terrestrial planets following impacts by bolides, only about one-third are ejected out of the solar system via the gravitational influences of Jupiter and Saturn. Even during the heavy bombardment phase of solar system development, the ejected rocks originating from the surface of one terrestrial planet would have only a  $10^{-4}$  probability of landing in a terrestrial planet in another solar system. Melosh (2003) concluded that lithopanspermia between solar systems is "overwhelmingly unlikely." Other investigators believe the odds are actually much greater (Belbruno *et al.* 2012) particularly when involving transfer between stellar systems forming in galactic clusters as they are much closer together (Adams and Spergel 2005).

Although various scenarios abound, it's been proposed that stars and protoplanets first form in galactic clusters within turbulent nebular clouds amongst thousands of other new born stars (Adams 2010; Fragkou *et al.* 2019; Johansen and Lambrechts 2017; Jones *et al.* 2019) with planets taking up to 10my to become established (Lissauer 1993). These protoplanets are presumably fashioned in these stellar nurseries by the accumulation of stellar debris, and with protoplanets of varying size crashing into one another prior to and after initially becoming captured by a newly forming stellar system (Boyle and Redman 2016; Joseph and Schild 2010a,b; Stephan *et al.* 2020). For example, Adams (2010) calculated that stars are born in clusters of 1,000–10,000 other stars; and with increased density, the probable successful transfer of life-bearing debris increases accordingly.

It has been hypothesized that stars and planets remain in those clusters for 10my to 30 My or longer (Adams and Myers 2001). Therefore, as worlds are formed and destroyed (Adams and Spergel 2005; Boyle and Redman 2016; Stephan *et al.* 2020) life may be repeatedly transferred between these protoplanets, carried by the billion trillion tons of debris that ricochet between these worlds during this 10 to 30 mya episode of supreme chaos and turbulence (Gibson *et al.* 2011; Joseph and Schild 2010b; Valtonen *et al.* 2008). Therefore, after becoming contaminated with life, these stars (and billions of planets) will drift away or are ejected thereby becoming independent, albeit, initially relatively chaotic solar systems until they stabilize.

## 4 Habitability and the Heavy Bombardment Phase of Solar System Formation

The proto-planets that would become Earth, Mars, and Venus may have become contaminated with life before and after this solar system was established. The early solar system was repeatedly subjected to cataclysmic events and cosmic collisions, which led to major changes affecting the habitability of the planets orbiting within the inner solar system.

Mars, Venus, Earth and the Moon, were repeatedly and continually bombarded by meteors, asteroids, comets, oceans of ice, and moon-sized debris until approximately 3.8 billion years ago (Chambers and Lissauer 2002; Levison *et al.* 2001, 2002; Zappalà *et al.* 1998). The Late Heavy Bombardment period is believed to have been triggered by the capture and rapid inward migration of the planets which resulted in cosmic collisions and the chaotic displacement of surrounding and adjacent debris fields, thereby triggering the delivery of planetesimals, asteroids, meteors, and oceans of water to the inner solar system (Kring and Cohen 2002; Tagle 2008); debris and water that may have harbored life.

Because Earth was continually bombarded, surface rocks already established prior to 4.2 bya were pulverized and vaporized erasing any evidence of life on the surface. However, once surface rocks, minerals, and metals began to cool and solidify, biochemical residue indicative of life began to fossilize, and thus there is evidence of life within Earth's oldest rocks, minerals and metals, dated to over 4.2 bya (Nemchin *et al.* 2008; O'Neil *et al.* 2008); and which suggests, life was present from the very beginning. Thereafter, and because Earth orbits within the habitable zone, life began to proliferate and terraform the biosphere (by releasing oxygen and other gasses), and evolve (Joseph 2000, 2010a,b).

Earth, Mars, and Venus, all orbit within the habitable zone, the inner and outer edges of which are located respectively at distances of 0.836 and 1.656 AU from the Sun (Kane and Gelino 2012). Therefore, Mars (1.52 AU) is located near the outer edge, while Venus (0.72 AU) is located just within the inner edge of the habitable zone (Kasting *et al.* 1993). Hence, if each of these planets had become contaminated with life during the protoplanetary stage of development, then, at least initially, life may have also begun to proliferate and evolve once their orbits stabilized.

Many scientists agree that ancient Mars was wet and habitable (Ehlmann *et al.* 2011; Grotzinger *et al.* 2014;

Squyres and Knoll 2005; Thomas-Keprta *et al.* 2009; Vago *et al.* 2017). Paralleling the onset and proliferation of life on Earth, there is evidence—but no conclusive proof—of life on Mars between 3.7 to 4.2 bya (Clement *et al.* 1998; Noffke 2015; Joseph *et al.* 2019; Thomas-Keprta *et al.* 2009). Moreover, Martian life may have proliferated and evolved to the level of metazoans (Joseph and Armstrong 2020; Joseph *et al.* 2020a; McKay 1996); after which, due to cosmic collisions or unknown catastrophic events, the Martian geodynamo was negatively impacted resulting in the loss of its magnetic shield (Acuña *et al.* 1999; Arkani-Hamed and Boutin 2004; Roberts *et al.* 2009). For example, it is believed that billions of years ago a planet or moon slammed into the northern plains of Mars creating an elliptical depression 6,600 miles long and 4,000 miles wide (Andrews-Hanna *et al.* 2007) and which may explain the extreme elliptical orbit of Mars. However, when and why it lost its geodynamo is unknown; but in consequence, Mars was no longer protected from solar winds and UV Rays, and suffered atmospheric loss and a cooling and aridification of its climate (Fairén 2017; Jakosky *et al.* 2018). Mars, therefore, became a failed Earth; though how long before the Martian oceans began to evaporate or freeze, is unknown.

Venus may have also been habitable billions of years ago (Abe *et al.* 2011; Cockell 1999; Joseph 2019), and may have remained habitable and able to sustain a variety of life forms until at least 700 million years ago, before it lost its oceans (Way *et al.* 2016) and its atmosphere exceeded the ultimate stage of the “moist greenhouse” effect:  $T_s \geq 330$  K (Wolf *et al.* 2017). When and what caused this catastrophic alteration in the habitability of Venus is unknown. In consequence, the environment of Venus became so toxic that only hyper-extremophiles would be able to survive; *i.e.* fungi and organisms beneath the surface (Joseph 2019; Ksanfomality 2013), or those dwelling in the clouds (Konesky 2009; Limaye *et al.* 2018; Sagan and Morowitz 1967; Schulze-Makuch *et al.* 2004); and for which there is evidence, but no proof.

It is also believed that over 4.4 billion years ago a Mars-sized planet may have struck Earth with so much force that the ejected mass formed the moon (Belbruno and Gott III 2005). Therefore, Earth was originally a super Earth, much larger in size, before this solar system stabilized. If life had already taken root on Earth during the protoplanetary phase of development, then, according to this hypothesis, what would become the moon would have also been infested with life that later became extinct, after this Earth-moon impacting-ejection event.

Considered as a hypothetical, if various protoplanets had become contaminated with life, there is no guarantee life would survive. Life, at least on the surface of these

worlds, may be subject to mass extinctions if these planets assume orbital trajectories outside the habitable zone and under conditions where water completely evaporates or becomes permanently frozen. For example, it's been estimated that the highest surface temperature threshold for a planet's habitability is most likely 82°C. Above this threshold, the loss of water by vaporization is irreversible and the oceans disappear completely in a few million years (Ingersoll 1969; Kasting 1998; Kasting *et al.* 2014; Wolf and Toon 2015). However, this does not preclude the possible existence of "alien" life forms with an adaptive biochemistry completely unlike the life of Earth.

Although those events leading to the possible ejection of what became the moon may have led to the extinction of any life on the lunar surface, this same catastrophic event may have enhanced the evolutionary potential for life on Earth. After ejection and/or after the moon began to orbit Earth, the Earth-Moon system's tidally driven processes decreased Earth's rotation period over the ensuing billions of years according to the following estimates: 4.5 bya = 6.1 h; 3 bya = 10.5 h; 2 byr = 14.2 h (Arbab 2009). The presence of the moon also altered the stabilization of Earth's obliquity (Laskar *et al.* 1993) which is subject to variations of  $\pm 1.3^\circ$  around a mean value of  $23.3^\circ$ . If there was no moon, these variations would range from nearly  $0^\circ$  up to about  $85^\circ$ , causing cataclysmic alterations in the climate and biosphere. As Earth would have also been larger—if the moon had not been ripped from the surface—so to would be the effects of gravity. In total, without the moon, there would have been profound effects on the trajectory and evolution of life such that humans may have never evolved on this planet.

## 5 Meteors, Ejecta, and the Interplanetary Transfer of Life

It is believed that Earth, Mars, and Venus were struck millions of times during the period of heavy bombardment which ended around 3.8 bya (Melosh 2003; Schoenberg *et al.* 2002). Given evidence of life on Earth between 4.2 and 3.7 bya (Nemchin *et al.* 2008; Nutman *et al.* 2016; O'Neil *et al.* 2008; Rosing and Frei 2004), and evidence of life on Mars during this same time period (Clement *et al.* 1998; Noffke 2015; Thomas-Keprta *et al.* 2009) each of these impacts would have also ejected tons of life-bearing debris into space (Beech *et al.* 2018; Belbruno *et al.* 2012; Worth *et al.* 2013). As argued by Belbruno *et al.* (2012): This period of massive bombardment, therefore, provided a major "window of opportunity" for the transfer of life-bearing debris

between planets. According to Worth *et al.* (2013): "such transfers were most likely to occur during the Late Heavy Bombardment." Hence, the parallels in the possible microbial colonization of Earth and Mars between 3.7 and 4.2 bya. However, the interplanetary transfer of life, within this solar system likely continued over the ensuing billions of years following meteor strikes (Beech *et al.* 2018; Belbruno *et al.* 2012; Worth *et al.* 2013) and due to powerful solar winds (Joseph 2009; Joseph *et al.* 2019).

It is well established that an ounce of soil contains billions of microbes, as well as protozoa, algae, fungi, lichens, and nematodes (Alexander 1991; Sylvia *et al.* 2004). If a ton of compacted soil were ejected into space, an estimated 32,000,000,000,000 adhering organisms might be buried inside and then subsequently deposited on another planet. As will be explained, a variety of species, including bacteria, algae, fungi, and lichens can survive a violent ejection from the surface of a planet, direct exposure to space, and then the crash landing onto the surface of a planet; though if they survive would depend on how long they are aloft, the matrix in which they are buried, and the habitability of the planet upon which they might be deposited.

According to calculations by Beech *et al.* (2018), given an impact velocity greater than 23 km/s, this microbial-laden ejecta could enter the orbits of and intercept Venus, Mars and other planets within a few weeks, months or years. Moreover, studies have demonstrated that bolide ejecta provides nutrients that can sustain trillions of microorganisms, including algae and fungi, perhaps for thousands of years (Mautner 1997, 2002). However, ejecta may remain in orbit for millions of years, whereas yet others may never strike another planet and instead fall into the sun (Gladman *et al.* 1996; Melosh 2003).

There are currently 200 known terrestrial impact craters that are still visible (Earth Impact Database 2020). Following the end of the great bombardment period, this planet may have been struck thousands of times (Melosh 1989), which resulted in the ejection of millions of rocks, boulders and tons of debris into space over the course of the last 4 billion years (Beech *et al.* 2018; Gladman *et al.* 1996; Melosh 1989, 2003; Van Den Bergh 1989). On Earth, in the last 550 million years there have been a total of 97 major impacts, leaving craters at least 5 kilometers across (Earth Impact Database 2020), and it's been estimated that approximately  $10^{13}$  kg of potentially life-bearing matter has been ejected from Earth's surface into the inner solar system" (Beech *et al.* 2018). These impacts may have ejected not just microorganisms, but metazoans, as well as seeds and plants resulting in the interplanetary transfer of even complex organisms between planets and influencing and impacting the evolution of life on alien worlds as well as on

Earth due to the possible survival and proliferation of any organisms buried in those meteors, asteroids and comets, that struck this planet (Joseph 2000).

Consider, for example, the Chicxulub crater, formed approximately 66 Mya, and which has a 150 km diameter (Alvarez *et al.* 1980). If that impacting asteroid also contained viruses, bacteria, and other living organisms as part of its cargo, is unknown; but if so, it is reasonable to ask if surviving extraterrestrial bacteria and viruses may have sickened life on this planet (Joseph and Wickramasinghe 2010) perhaps contributing to the demise of the dinosaurs and/or influencing the evolutionary trajectory of survivors via horizontal gene transfer (Joseph 2000). In addition to the possible extraterrestrial delivery of living organisms to Earth 66mya and creating conditions that led or contributed to the demise of the dinosaurs (Alvarez *et al.* 1980), it's been estimated, given a 25 km/s impactor velocity, that up to  $5.5 \times 10^{12}$  kg of debris may have been ejected into space when that asteroid struck (Beech *et al.* 2018). That debris may have included unknown volumes of water, and perhaps millions of trillions of organisms buried within this ejecta. Those that survived and were deposited within a habitable environment, would have likely gone forth and multiplied.

The Chicxulub crater is just one example of an impact-ejection event. Earth, Mars and Venus were repeatedly struck by asteroids and meteors. Over 635,000 impact craters at least 1 km (0.6 miles) wide, have been located on Mars (Robbins and Hynek 2012), approximately 1000 impact craters have been detected on Venus by the Magellan spacecraft (Schaber *et al.* 1992) and 200 large terrestrial impact craters have been located on Earth (Earth Impact Database 2020)—whereas the number of those that did not survive weathering or were eventually buried, is unknown. Of the 60,556 meteorites so far found on Earth, 227 are believed to have originated on Mars, and 360 are from the Moon (Meteoritical Bulletin Database 2020). Meteors from Venus have not yet been identified. Clearly these planets have been repeatedly impacted by meteors which survived descent through the atmosphere without vaporization. Innumerable organisms embedded deep within those impacting meteors may have also survived.

## 6 Surviving Impact, Ejection, Exposure to Space and Crash Landing

It is well established that microbes buried within debris, can survive extreme and violent shocks and impact pres-

ures of 100 GPa, and the subsequent hyper-velocity launch into space (Burchell *et al.* 2004, 2001; Hazael *et al.* 2017; Horneck *et al.* 2008; Mastrapa *et al.* 2001). By forming spores, they can even survive long term direct exposure to the frigid temperatures and vacuum of space despite the cosmic rays, gamma rays, UV rays, ionizing radiation they encounter (De la Torre Noetzel *et al.* 2017, 2020; De Vera *et al.* 2014, 2019; Horneck *et al.* 2002; Olsson-Francis *et al.* 2009). There is also a high probability of survival after the crash landing onto the surface of a planet (Burchell *et al.* 2001; Horneck *et al.* 2002; Szewczyk *et al.* 2005).

Although innumerable meteors disintegrate, it's been estimated that those at least ten kilometers across will punch a hole in the atmosphere and continue their descent; and upon striking the surface eject tons of dust, rocks, boulders and other debris into space (Covey *et al.* 1994; Hara *et al.* 2010; Van Den Bergh 1989); with some of that debris possibly passing through that atmospheric hole before air can rush back in thereby preventing excessive heating (Van Den Bergh 1989). Other than initial shock pressures, these masses of ejecta, and surviving organisms buried within, would not be subject to extremes in heat.

When a comet, asteroid, or meteor passes through the atmosphere and strikes the surface, rocks, boulders and debris that are blown upward and ejected by the impact, may pass back through the atmosphere; and in consequence they may be heated to temperatures in excess of 100°C if they pass through after that "hole" has closed up (Artemieva and Ivanov 2004; Fritz *et al.* 2005). These temperatures are well within the tolerance range of thermophiles (Baross and Deming 1983; Kato and Qureshi 1999; Stetter 2006). Spores can survive shock temperatures of over 250°C (Burchell *et al.* 2004; Horneck *et al.* 2002). Therefore, if the hole in the atmosphere closes up before that ejecta can pass through, the friction-generated heat might only kill those organisms riding on the surface. In addition, exterior heating may only last a few seconds, whereas ejecta may be covered by a heat-induced fusion crust of at least 1 mm, which acts as a protective heat shield for organisms deep within (Cockell *et al.* 2007); as the thermal pulse may only extend a few millimeters below the surface due to low thermal conductivity. Thus, organisms buried within will not be affected. In fact, the interior may never be heated above 100°C as the ejecta-surface is acting as a heat shield (Burchell *et al.* 2004; Horneck *et al.* 2002).

Microbes can also resist the shock of a violent impact casting them into space (Mastrapa *et al.* 2001; Burchell *et al.* 2004, 2001). Bacteria, yeast spores and microorganisms can survive impacts with shock pressures of the order of gigapascals (Burchell *et al.* 2004; Hazell *et al.* 2010; Meyer *et al.* 2011; Willis *et al.* 2006). Meyer *et al.* (2011) has demon-

strated that bacteria and lichens can survive powerful shock waves and pressures up to 45 GPa, whereas cyanobacteria withstand up to 10 GPa; so long as these organisms are embedded within low porosity rocks.

Further, a substantial number of organisms could easily survive not just the ejection from a planet, but the descent to the surface (Burchell *et al.* 2001; Horneck *et al.* 2002; McLean and McLean 2010). In one study, granite samples were permeated with spores of *Bacillus subtilis* and attached to the exterior of a rocket and launched into space, reaching a maximum atmospheric entry velocity of 1.2 km/s and temperatures of 145°C (Fajardo-Cavazos *et al.* 2005). Although a massive die off was recorded, up to 4.4% directly exposed to these conditions survived—and one survivor can easily reproduce billions of microbial offspring. By contrast, studies have shown that a significant number of organisms buried within a meteor will not be unduly harmed even when crashing into a planet (Burchell *et al.* 2001; Horneck *et al.* 2002; McLean and McLean 2010). Moreover, there are high survival rates following high atmospheric explosions, *i.e.* the Columbia space shuttle explosion (Szewczyk *et al.* 2005), and despite reentry speeds of up 9700 km h<sup>-1</sup> (McLean *et al.* 2006). Thus, innumerable microbes may remain viable despite violent impact-induced ejection into space and the rapid descent to the surface of another planet.

Earth is an obvious source of living organisms that may have been ejected, jettisoned, cast into space, only to crash onto the surface of other worlds in this solar system beginning over 3.8 bya, thereby repeatedly seeding Venus, Mars, and other planets with life (Beech *et al.* 2018; Fajardo-Cavazos *et al.* 2007; Hara *et al.* 2010; Melosh 2003; Mileikowsky *et al.* 2000a,b; Schulze-Makuch *et al.* 2005) and vice-versa. Asteroids and meteors striking Earth may have repeatedly sheared away masses of earth and rock, and blasted this material (and presumably any adhering microbes, fungi, algae, and lichens) into space (Beech *et al.* 2018; Gladman *et al.* 1996; Hara *et al.* 2010; Melosh 2003; Mileikowsky *et al.* 2000a,b), where they can survive (Horneck *et al.* 2002; Onofri *et al.* 2012; De Vera *et al.* 2019; De la Torre Noetzel *et al.* 2020; Novikova 2009; Novikova *et al.* 2016; Olsson-Francis *et al.* 2009). Some of this microbe-laden debris may have later crashed on Mars (Hara *et al.* 2010; Schulze-Makuch *et al.* 2005) where, as demonstrated by simulation studies, a variety of organisms can also survive (Cockell *et al.* 2005; Mahaney and Dohm 2010; Osman *et al.* 2008; Pacelli *et al.* 2016; Sanchez *et al.* 2012; Selbman *et al.* 2015); and the same may be true of organisms deposited in the upper clouds of Venus (Joseph 2019; Konesky 2009; Limaye *et al.* 2018; Sagan and Morowitz 1967; Schulze-Makuch *et al.* 2004). Coupled with solar winds blowing high

altitude atmospheric organisms into space (Arrhenius 1908; Joseph 2009) the interplanetary transfer of microorganisms within our Solar System is overwhelmingly likely (Beech *et al.* 2018; Joseph *et al.* 2019; Mileikowsky *et al.* 2000a,b).

## 7 Spores and Space Travel

In the absence of water, nutrients, or under extreme life-neutralizing conditions, microbes, lichens, fungi and other organisms may instantly react by forming highly mineralized heat or cold shock proteins that enclose and wrap around their DNA, thereby eliminating all need for metabolism and altering the chemical and enzymatic reactivity of its genome making it nearly impermeable to harm (Marquis and Shin 1994; Setlow and Setlow 1995; Sunde *et al.* 2009). A dormant spore survives exposure to extreme heat, cold, desiccation, the vacuum, UV and ionizing radiation of space with just minimal protection (Horneck 1993; Horneck *et al.* 1995; Mitchell and Ellis 1971; Nicholson *et al.* 2000). Survival rates also increase significantly, up to 70%, if coated with dust or salt crystals (Horneck *et al.* 1994). Although the full spectrum of UV rays are deadly against spores, some spores, including *B. subtilis* can even survive a direct hit (Horneck *et al.* 2002). If buried below 30 cm of surface material the effects of heavy ions and secondary radiation depreciates significantly and survival rates dramatically increase (Horneck *et al.* 2002). Because of their small size, it's been estimated that even those near the surface of ejecta may survive in space for millions of years being struck by radiation; and up to 25 million years in space if shielded by 2 meters of meteorite (Horneck *et al.* 2002).

Many species of microbe form colonies. If traveling through space, those in the outer layers would therefore create a protective outer colonial crust that blocks out radiation and protects those in the inner layers from the hazards of space (Nicholson *et al.* 2000). Therefore, colonies of living microbes provide their own protection and need not form spores.

As noted, ejected debris may orbit in space for millions of years before striking another planet. Microbes, lichens, and fungi may survive life in space for tens of millions of years via the formation of spores. Cano and Borucki (1995) have reported that spores, embedded in amber, may remain viable for 25- to 40-million-years. Vreeland *et al.* (2000) have reanimated 250 million-year-old halotolerant bacteria from a primary salt crystal, whereas Dombrowski (1963) reanimated spores "isolated from salt deposits from the



Middle Devonian, the Silurian, and the Precambrian" that were over 600 million years in age.

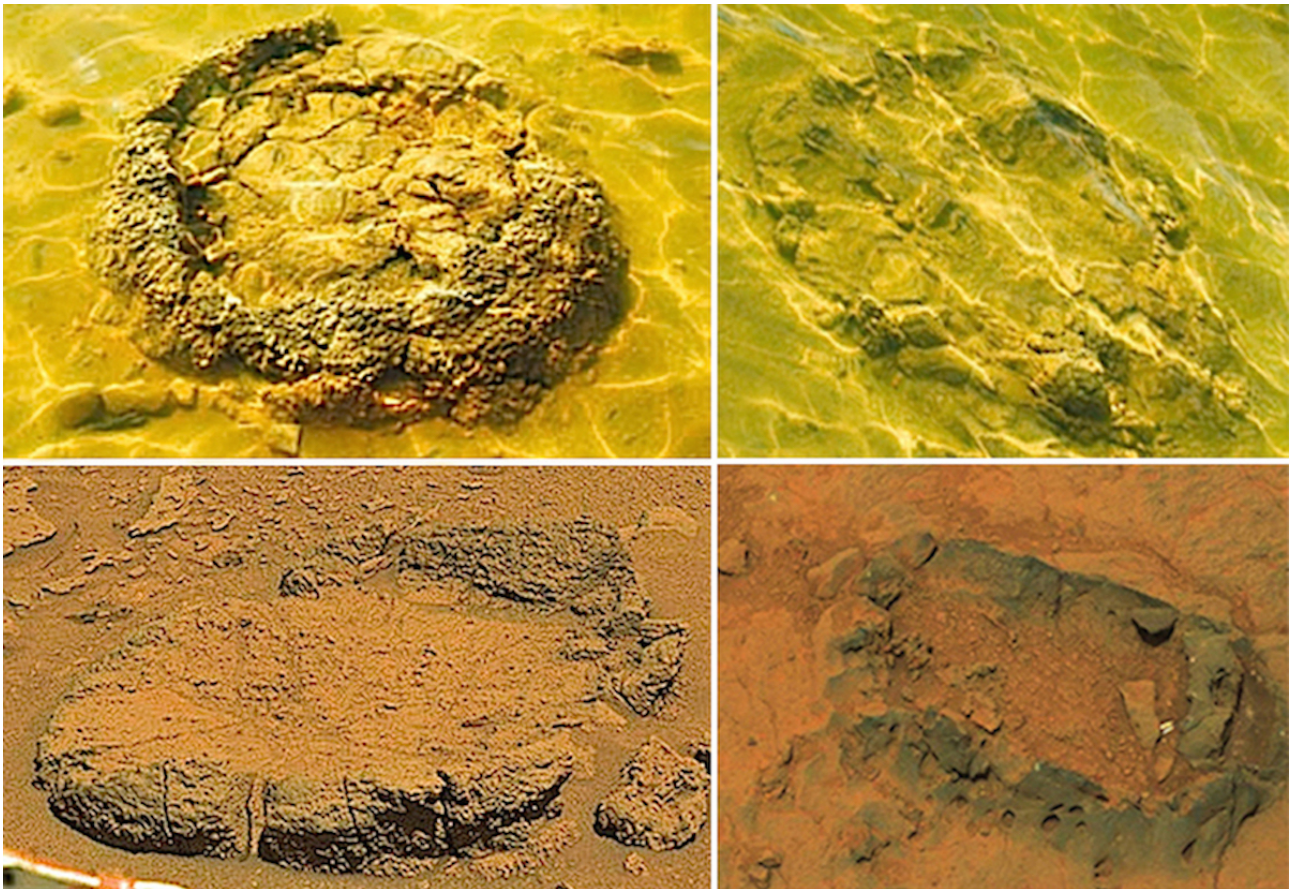
Therefore, even if ejecta circulates in orbit for millions or tens of millions of years, spores embedded beneath the surface might survive; and if they land on Mars and in the clouds of Venus, those which can adapt would likely go forth and multiply.

## 8 Evidence of Life and Stromatolites on Mars: Parallels with Earth

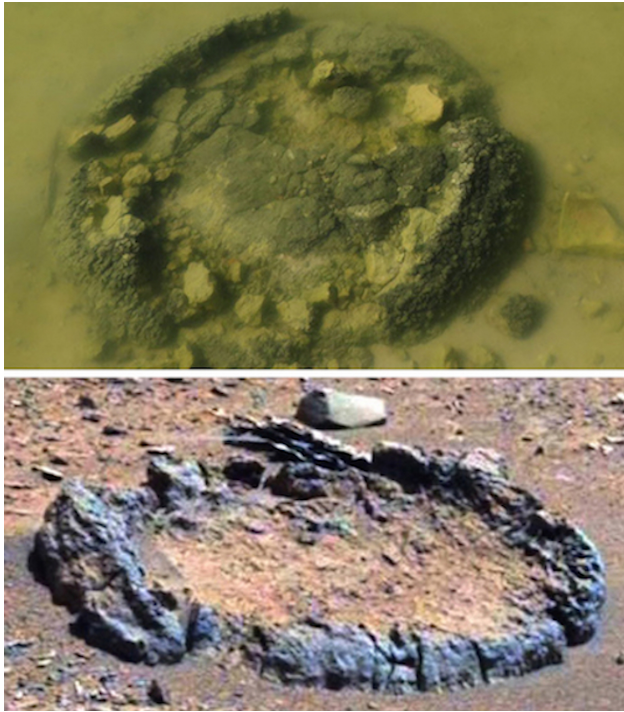
Although considered controversial, NASA's 1976 Viking Labeled Release studies, at two landing sites 4,000 miles apart on Mars, detected evidence of surface biological activity that could be attributed to a very wide range of microorganisms including aerobic and anaerobic bacteria, as well as lichens, fungi, and algae (Levin and Straat 1976, 1977, 2016).

Via the Viking "Gas Exchange" experiments, soil samples were also humidified at  $\sim 10^{\circ}\text{C}$  and a significant quantity of  $\text{O}_2$  was released (Oyama and Berdahl 1977). On Earth, the humidification of soil will cause a massive proliferation of photosynthesizing algae/cyanobacteria and an increase in oxygen production (Lin *et al.* 2013; Lin and Wu 2014). Levin *et al.* (1978) also observed "green patches" on rocks and hypothesized these may be algae. Therefore, the responses produced by the LR instruments and the "Gas Exchange" experiments, and the observations of Levin *et al.* (1978) support the likelihood of life.

In 1996, McKay and colleagues reported the discovery of "nanobacteria" in Martian meteorite ALH 84001; specimens so small that if they had a genome, it could only house RNA. These findings were immediately challenged. As summed up by Martel *et al.* (2012), "...structures resembling terrestrial life forms known as nanobacteria—can be deemed ambiguous at best." Although also subject to dispute (see Treiman 2003; Steele *et al.* 2012), evidence of biological residue, carbonates, and fossilized poly-



**Figure 1.** (Top row): Lake Thetis stromatolites with collapsed domed (Photo credit: Courtesy Government of Western Australia Department of Mines and Petroleum). (Bottom row) Left: Sol 529. Right: Sol 308. Photographed in Gale Crater: Martian specimens with evidence of concentric lamination and fossilized fenestrae. (From Joseph *et al.* 2020a, reproduced with permission).



**Figure 2.** (Top): Lake Thetis stromatolites with collapsed domed (Photo credit: Lyn Lindfield And TheTravellingLindfields.com, reproduced with permission). (Bottom) Left: Sol 122. Sol 308. Photographed in Gale Crater: Martian specimen with evidence of concentric lamination and fossilized fenestrae. (From Joseph *et al.* 2020a, reproduced with permission).

cyclic aromatic hydrocarbons (PAHs)—a byproduct of cellular decay—were also discovered in Martian meteorite ALH 84001 (Clement *et al.* 1998; McKay *et al.* 1996, 2009) at least 25% of which appears to be biological (Thomas-Keptra *et al.* 2009). Thomas-Keptra *et al.* (2009) has argued these findings are indicative of life on Mars over 4.2 bya. As summed up by Martel *et al.* (2012) "the presence of polycyclic aromatic hydrocarbons, magnetite crystals, carbonate globules... are compatible with living processes."

In 2002 DiGregorio reported what he believed to be biosignatures compatible with cyanobacteria in an ancient paleolake; a hypothesis based on the detailed analysis of images photographed at Utopia Planitia and Chryse Planitia—in the same locations where the Viking LR experiments detected biological activity and algae-like green patches were observed (Levin and Straat 1977, 2016). DiGregorio (2002), observed what he interpreted to be "rock varnish" typically produced by a wide variety of microorganisms "including epilithic and edolithic cyanobacteria." DiGregorio hypothesized that Martian cyanobacteria could have cemented sediments together, fashioning microbial mats and stromatolites in these ancient Martian lakes. Subsequently, in 2009, Rizzo and Cantasano (2009, 2017) re-

ported evidence of fossilized microbialites based on a detailed examination of Martian sediments resembling stromatolites. Additional evidence of microbialites, microbial mats, thrombolites and stromatolites were subsequently provided by numerous investigators (Bianciardi *et al.* 2014, 2015; Joseph *et al.* 2019, 2020a,c; Ruff and Farmer 2016; Small 2015).

Gale Crater is believed to have been host to several lakes which were repeatedly replenished, and these ancient bodies of water have been likened to the Lake Thetis of Western Australia which is also home to living and fossilized domical stromatolites. In March of 2020, a team of 14 experts in astrobiology, astrophysics, biophysics, geobiology, microbiology, lichenology, phycology, botany, and mycology conducted an extensive search of the NASA Mars Gale Crater image data base and found six concentric-domical Martian specimens that closely resemble Lake Thetis stromatolites; five of which appeared fossilized (Joseph *et al.* 2020a). This team also observed numerous other concentric structures, that although severely decomposed, still retained patterns similar to domical-concentric stromatolites.

Therefore, over a dozen surface features quite similar to stromatolites have been observed on Mars. It's been estimated that the oldest of these Martian stromatolites may be 3.7 billion years in age (Noffke 2015); a time period which coincides with the fashioning of what may be the first stromatolites on Earth 3.7 bya (Garwood 2012; Nutman *et al.* 2016)—though not all investigators accept this evidence.

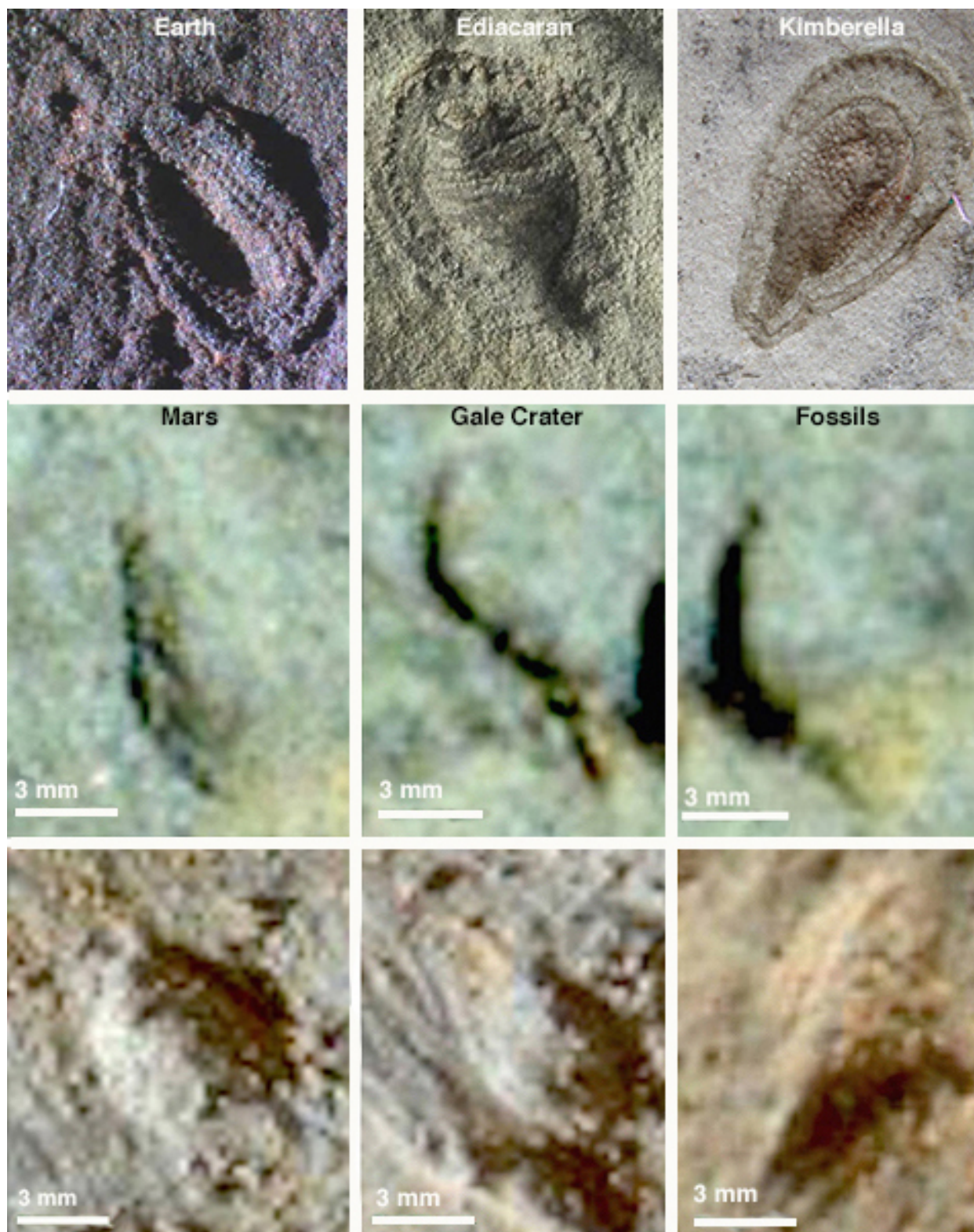
Hence, there is evidence (but no proof) that life may have appeared on Mars between 3.7 to 4.2 bya (Noffke 2015; Thomas-Keptra *et al.* 2009), and that stromatolite constructing-organism were proliferating (Joseph *et al.* 2020a); and this parallels the evidence, based on chemical and physical fossils, that life had also appeared on Earth during this same time period (Nemchin *et al.* 2008; O'Neil *et al.* 2008; Rosing and Frei 2004), some of which were also constructing stromatolites (Garwood 2012; Nutman *et al.* 2016), during and upon the close of the heavy bombardment phase when Earth, Mars, and Venus were pummeled with meteors, asteroids, comets and oceans of water that may have harbored life.

## 9 Fossils on Mars? Evolution and Interplanetary Transfer?

Beginning billions of years ago, life on Earth diversified, adapted to the changing environment, and evolved. By 800 to 600 mya, oxygen levels had significantly increased to about 0.1%–3% O<sub>2</sub>, of modern atmospheric levels (Ader



**Figure 3.** (First row): Sol 809 and Sol 869. (Second row) Sol 905 and Sol 905. Specimens photographed in Gale Crater and that are quantitatively and statistically nearly identical to Ediacaran fossils of *Namacalathus* (two, bottom left) and (with the exception of tail length) Cambrian fossils of Lophotrochozoa (three bottom right). Photos of *Namacalathus* reproduced from and courtesy of Kontorovich *et al.* 2008. Photos of Lophotrochozoa reproduced from and courtesy of Zhang *et al.* 2014.



**Figure 4.** (First row) fossilized remains of Ediacaran *Kimberella*. (Bottom two rows): Specimens photographed in Gale Crater, quantitatively and statistically nearly identical to Ediacaran fossils of *Kimberella*. Sol 809, Sol 809, Sol 809; Sol 880, Sol 905, Sol 905. Note proboscis and "zipper-like" appendages.

*et al.* 2014; Lyons *et al.* 2014) thereby leading to an explosion of oxygen-breathing life (Brocks *et al.* 2017; Lenton *et al.* 2014), that included acritarchs followed by Ediacaran metazoans (Erin 2015; Xiao *et al.* 2014; Zhou *et al.* 2001). Moreover, despite repeated catastrophic extinction events, life on Earth never became completely extinguished. Instead, each episode of mass extinction was followed by repopulation and evolutionary innovation (Eldredge and Gould 1972; Elewa and Joseph 2009; Joseph 2010a,b). Therefore, if life had taken root, then beginning after 3.7 bya life may have also evolved on Mars, up until that point in Martian history when catastrophic events negatively impacted its internal dynamo, thereby resulting in the loss of its magnetic shield, followed by the evaporation and freezing of its oceans and continual bleeding of atmosphere into space. However, although speculation abounds, it is unknown as to when these catastrophes occurred.

Paralleling events on Earth, Kaźmierczak (2016, 2020) upon searching the Mars Meridiani Planum data base, discovered specimens that resemble mineralized tri-star and globular fossils with central vesicle-like ornamental chambers. These mineralized spiny bimorphic structures have thin walls with a cell-like appearance and were discovered in hydrated sediments that may have once been an ancient lake, *i.e.* Endeavor Crater. According to Kaźmierczak (2016) analyses, morphologically they are similar to terrestrial fossils variably described as acritarchs (meaning “of uncertain origin”). The first acritarchs may have evolved, on Earth, over 700 million years ago (Aroui *et al.* 2000; Zhou *et al.* 2001). In addition, Kaźmierczak (2020) has presented evidence of Martian fossils that are strikingly similar to daughter colonies characteristic of *Terran volvocalean* algae as well as cell-like enclosures similar to chloroplasts and modern unicellular green and yellow green algae.

Martian fossils *resembling* metazoans have also been observed; many of which resemble one another and were found in the same location or on adjacent mudstones in Gale Crater (Joseph *et al.* 2020b). Subsequent, ongoing studies have identified over a dozen fossil-like impressions that are morphologically and statistically identical to Ediacaran fossils; *i.e.* *Namacalathus* and *Kimberella* (Joseph and Armstrong 2020). These fossils were embedded within and atop Martian mudstones upon the lower lake surface of Gale Crater; an area that other investigators believe was conducive to the proliferation and fossilization of marine organisms (Grotzinger *et al.* 2014, 2015). These metazoan-like fossils, most protruding from the surface, included spiral, spherical, and tubular specimens often atop or immediately adjacent, and many nearly identical to one another (Joseph *et al.* 2020a). As determined by molecular clock studies, metazoans began populating Earth 750 to 800 mya

(Erin 2015) although the first fossil evidence of metazoans (the Doushantuo embryos) do not appear in the geological record until 600 mya (Xiao *et al.* 2014).

It must be stressed: There is no conclusive proof these are Martian metazoan fossils. Nevertheless, it is reasonable to ask: Is it possible that metazoans evolved on Mars? Or were they deposited on the Red Planet following meteor strikes and ejection from Earth?

McKay (1996) has argued that “after the origin of life the key evolutionary steps could have occurred much more rapidly on Mars than on Earth” and that within a billion years after life appeared, Mars may have “experienced the range of biological evolution that would be duplicated on the Earth only with the start of the Cambrian.”

However, if metazoans independently evolved on Earth and on Mars, then this would suggest that “evolution” is not random and does not unfold according to Darwinian principles, but is genetically coded and follows precise genetic principles; such that similar species inevitably “evolve” on planets that are similarly habitable; a genetically governed and regulated process that Joseph (2000) has likened to embryology and “evolutionary metamorphosis.”

Joseph (2000) has also speculated that since so many Ediacaran and Cambrian species were of unknown origin, that possibly the Cambrian explosion may have been due to the interplanetary transfer of life: “until around 600 million years ago, just prior to the Cambrian era, the vast majority of life forms sojourning on Earth consisted of single celled organisms and simple multi-celled creatures composed of less than 11 different types of cells. And then there was a sudden explosion of complex life, including rather “bizarre” life forms that appeared simultaneously and multi-regionally throughout the oceans of the Earth” including numerous species that have an “unknown origin.” Joseph (2000) goes on to argue: “Many creatures (including even complex multicellular plants, insects, frogs and lizards) can also live in a dormant form and withstand otherwise life neutralizing conditions. Indeed, the capacity to live in a dormant state even under environmental extremes, may well account not only for the origin of life on Earth, but to the sudden emergence of at least some of the complex species during the Cambrian Explosion. In other words, even complex animal life may have been deposited on Earth from outer space, including, perhaps at least some of the “bizarre” life forms that emerged during the Cambrian Explosion.”

*Caenorhabditis elegans* is a metazoan, approximately 1mm in length and has a mouth, intestine, male and female reproductive organs, and an ancestry that extends back to the Ediacaran era. *C. Elegans* is a nematode, and some species of nematode prefer frigid climates (Mullin *et al.*

2002), where temperatures may fall below  $-50^{\circ}\text{C}$  ( $-58^{\circ}\text{F}$ ). Conversely, those that dwell in arid environments can enter a state of dormancy for up to 28 years if deprived of water and then become metabolically active when provided moisture (Fielding *et al.* 1951). *Caenorhabditis elegans*, therefore, might be capable of adapting to life on Mars. They can also survive exposure to space, an explosive reentry into the atmosphere, and a subsequent crash landing.

On February 2, 2003, numerous members of this species, ensconced within canisters, survived an explosion, at speeds of Mach 19, approximately 61 km above Earth's surface, that destroyed the space shuttle Columbia. And these *C. elegans* survived an unprotected 660–1,050 km/h velocity reentry into Earth's atmosphere and the subsequent crash upon the surface (Szewczyk *et al.* 2005). After these *C. elegans* were retrieved from the crash site all but two displayed normal growth and reproductive egg laying behavior. As argued by (Szewczyk *et al.* 2005), what they experienced is analogous to being embedded on the surface of an asteroid that breaks into fragments upon striking the atmosphere, and then surviving after those fragments smash into the ground

Eight hundred million years ago, the Moon and Earth, were struck by a flurry of asteroids that likely profoundly affected the biosphere (Terada *et al.* 2020). As summarized by Terada *et al.* (2020): "Based on crater scaling laws and collision probabilities... meteoroids, approximately 30–60 times more powerful than the Chicxulub impact, must have plunged into the Earth-Moon system."

Soon thereafter, acritarchs, Ediacarans, and thus, the first metazoans, began to proliferate in Earth's oceans, many having a bizarre appearance, many eventually dying out and becoming extinct, and many have a completely unknown ancestral origin—as if they were deposited here from another planet.

If the hypothesis of McKay (1996) and Joseph (2000) are correct, it is reasonable to ask: is it possible that Martian metazoans were transported to Earth, thereby contributing to or giving rise to the Cambrian Explosion? Or, might the (presumed) metazoans on both planets have originated from another world; possibly buried in those meteors that struck 800mya? Or, conversely, did ejecta from Earth transport metazoans to Mars? One can only speculate.

## 10 Fossils on the Moon?

In support of the interplanetary transfer hypothesis is the discovery of fossilized impressions on the surface of the moon. Specifically, in 1970 lunar soil samples were returned

to Earth by the Luna 16 spacecraft in a hermetically sealed container (Rode *et al.* 1979) and one of the specimens was observed to closely resemble a spiral filamentous micro-Ediacaran, a species which became extinct over 500,000 years ago (Joseph and Schild 2010a). Zhmur and Gerashenko (1999), also identified what they believed to be lunar microfossils of coccoidal bacteria; *i.e.* siderococcus and sulfolobus. It is not probable that Ediacarans and coccoidal bacteria evolved on the moon. Therefore, if these fossilized impressions are true fossils, they must have been transported to the lunar surface, possibly while still alive, and became fossilized.

Moreover, what appears to be microfossils of ovoid and elongated nanobacteria were also discovered in a lunar meteorite (Sears and Kral 1998). These lunar "nanobacteria" however, were even smaller than the "nanobacteria" discovered in Martian meteorite ALH8401. In general "nanobacteria" are so small it would be impossible for them to host a DNA-based genome, but only an RNA-based genome, like a virus. If we employ life on Earth as a standard, it is not likely that the Martian or Lunar "nanobacteria" are true cellular organisms (Joseph and Schild 2010b).

## 11 Lunar Life and Survival of the Fit

After sitting 3 years on the moon, a TV camera from the lunar Surveyor Space Craft was retrieved by Apollo 12 astronauts, and dormant bacterium (*Streptococcus mitis*) were found within. Mitchell and Ellis (1971), the scientists who made this discovery, ruled out contamination due to a scientist's sneeze or cough because a single droplet of saliva contains an average of 750 million organisms and billions of bacteria and a "representation of the entire microbial population would be expected," rather than a single species that was dormant and then came back to life. Mitchell and Ellis (1971) therefore, left open the possibility that the camera was contaminated on the moon by lunar *Streptococcus mitis*; and not before the camera was sent and not after it was returned from the lunar surface.

It is possible, however, that there was contamination and that billions of diverse moisture-dwelling bacteria were coughed or sneezed into this equipment prior to sending the TV camera to the moon. Possibly, a diverse colony of organisms were subsequently transported to the lunar surface within that camera, and only *Streptococcus mitis* survived by forming spores and all other bacteria died leaving not a trace of their existence. Likewise, it can be argued that only those organisms which can survive ejection from Earth, Mars, or some other planet, and that can survive the

subsequent exposure to the intense UV and gamma radiation of space, may go forth and multiply when deposited on a habitable, watery moon or planet. By contrast, those that cannot survive a journey through space and which are deposited on completely uninhabitable moons or planets, will die, decompose, or, more rarely, their remains may be fossilized.

## 12 Solar Winds vs Microbes in the Stratosphere and Mesosphere

Fungi, lichens, and algae and over 1,800 different types of bacteria flourish within the troposphere, the first layer of Earth's atmosphere (Brodie *et al.* 2007). Microbes, algae, fungi, lichens, spores, insects, larva, pollen, seeds, water, dust and nematodes are often transported to the stratosphere and mesosphere due to tropical storms, monsoons, thunderstorms, hurricanes, tornados, volcanic eruptions and seasonal and electrostatic upwellings of columns of air (Dehel *et al.* 2008; Holton *et al.* 1995; Randel *et al.* 1998; Rohatschek 1996; Van Eaton *et al.* 2013). Microorganisms, fungi, and spores have been recovered at 40 km, 61 km and 77 km above Earth (Imshenetsky *et al.* 1978; Soffen 1965; Wainwright *et al.* 2010). And once within the stratosphere they may be blown into space by powerful solar winds (Joseph 2009, 2019) where, as shown experimentally, they can survive (De la Torre Noetzel *et al.* 2020; De Vera *et al.* 2019; Horneck *et al.* 2002; Nicholson *et al.* 2000, 2003, 2005; Novikova *et al.* 2016; Olsson-Francis *et al.* 2009).

If the dispersal of upper atmospheric organisms into space occurs continually or only periodically every few years, decades or centuries, is unknown. However, on September 24, 1998, a series of coronal mass ejections created a shock wave and powerful solar winds that struck the magnetosphere with such force that oxygen, hydrogen, helium, water molecules and surface dust gushed from the upper atmosphere into space (Moore and Horwitz 1998; Schroder and Smith 2008). For most of every year, the solar pressure is around two or three nanopascals. However, on September 24, the pressure increased to ten nanopascals. Similar events may have occurred repeatedly and more frequently throughout Earth's history.

For example, data derived from the observation of solar proxies with different ages and reconstructions of the Sun's radiation and particle environment from 3.5 bya to the present "indicates a solar wind density up to 1000 times higher at the beginning of the Sun's main sequence lifetime" and that gradually dropped to current levels (Lammer *et al.* 2003). Thus, beginning billions of years ago air-

borne microbes, fungi, lichens, and algae, as well as water and dust lofted into the upper atmosphere, may have been swept into space by solar winds and dispersed throughout the solar system some of which may have landed on Mars, the Moon, and in the clouds of Venus (Arrhenius 1908; Joseph 2009, 2019).

## 13 Life in the Clouds of Venus

The clouds of Earth are saturated with water and life (reviewed by Joseph 2019). Venus has three cloud layers that contain high levels of deuterium and trace amounts of water (Barstow *et al.* 2012; Donahue and Hodges 1992), which could sustain life (Clarke *et al.* 2013; Cockell 1999; Grinspoon and Bullock 2007; Konesky 2009; Seckbach and Libby 1970; Schulze-Makuch *et al.* 2004). According to Limaye *et al.* (2018): "The lower cloud layer of Venus" provides "favorable conditions for microbial life, including moderate temperatures and pressures (~60°C and 1 atm)." Konesky (2009) has suggested that organisms similar to plankton may dwell in the upper atmosphere. Schulze-Makuch *et al.* (2004) hypothesized that Venusian clouds, 48 to 65 km above the surface, could harbor aeroplankton which engage in photosynthesis. Sagan and Morowitz (1967) hypothesized that complex multi-cellular organisms swim between the thick layers of Venusian clouds where they metabolize and generate hydrogen as propellants and a means of floatation. These scenarios are not unreasonable as trillions of billions of organisms dwell in the clouds of Earth and are therefore adapted to living in the upper atmosphere.

If life is being deposited in the clouds of Venus via bolides and solar winds from Earth, it is therefore possible that some of these organisms that survive the journey may adapt to life on Venus. However, the possibility of life in the clouds of Venus is a hypothesis, and not fact.

## 14 Life Upon and Beneath the Surface of Venus

The Russian probe Venera 13 landed in the Beta-Phoebe region of Venus in an area described as a "stony desert" (Surkov *et al.* 1983). On Earth, endolithic microorganisms flourish in hyper-arid stony deserts and under extreme environmental conditions by colonizing the interior and undersides of rocks (Weirzchos 2012; Pointing and Belnap 2012) within which water molecules may be trapped. Gen-

erally, these hot desert micro-habitats are dominated by lichens, fungi, algae, cyanobacteria and heterotrophic bacteria (Pointing and Belnap 2012).

The surface temperature of Venus, as determined by Venera 7, is  $739\text{ K}/465.85^\circ\text{C}$  (Avduevsky *et al.* 1971). There are no known terrestrial organisms which can survive these temperatures, except, perhaps, as spores. However, basalt is common on Venus, and basalt has high thermal insulating properties (Eppelbaum *et al.* 2014). Temperatures beneath these rocks, and up to 10 m below the surface, would be much cooler than the surface (Joseph 2019) as documented on Earth (Al-Temeemi and Harris 2001; Smerdon *et al.* 2004). In high temperature environments heat transfer reduction from the surface to 10 m down can be as much as 57% (Al-Temeemi and Harris 2001); *i.e.* 43% of surface temperature. As calculated by Joseph (2019), at a depth of 1 m temperatures on Venus might average  $407.4^\circ\text{C}$  whereas at 10 m, the subsurface temperature may average  $305.3^\circ\text{C}$  which is within the limit for the hardiest hyperthermophiles on Earth (Kato and Takai 2000). Some hyperthermophiles have been discovered thriving adjacent to  $400^\circ\text{C}$  thermal vents (Stetter 2006). However, there are no known terrestrial species which can survive direct exposure to temperatures above  $300^\circ\text{C}$  (Kato and Qureshi 1999; Kato and Takai 2000).

Venus orbits in the habitable zone, and in addition to comets, asteroids, and meteors, large amounts of frozen water was likely delivered to the surface early in this planet's history. Possibly, Venus had oceans as recently as 700 million years ago (Way *et al.* 2016) and was likely habitable billions of years ago (Abe *et al.* 2011; Cockell 1999). If the catastrophic change in the biosphere of Venus was sudden or took place over millions of years is unknown. However, if Venus was habitable and inhabited billions of years ago, from what we know of the adaptive nature of microbial and other forms of life, even a drastically changing environment does not obliterate all life. Some organisms form spores, others evolve and adapt. Likewise, if there had been life on Venus, to survive they would have had to adapt and evolve to these hyper-extreme conditions.

## 15 Fungal Life on Venus?

Any organisms that evolved in response to the changing Venusian biosphere would require water which also might be available in the clouds and below ground. For example, just as occurs in the deserts of Kuwait, moisture and water may be drawn up from the subterranean depths (Al-Sanad and Ismael 1992). If so, Venusian organisms living below

ground may be continually supplied with water as it rises to the surface and before it completely evaporates.

It is also well established that numerous species are able to colonize and flourish within even the most toxic and seemingly-life-neutralizing environments, including pools of radioactive waste (Armstrong 2017; Dighton *et al.* 2008; Durvasula and Rao 2018; Gerday and Glansdorff 2007; Zhdanova *et al.* 2004). It's also been demonstrated that some species can survive in Venusian analog environments (Seckbach *et al.* 1970). It's been hypothesized that thermophilic phototrophs (Arrhenius 1908; Cockell 1999), algae (Seckbach and Libby 1970) and acidophilic microbes (Schulze-Makuch *et al.* 2004) could flourish within the Venusian biosphere. Moreover, as reported by Joseph (2019) it appears that fungi are hyper-extremophiles capable of colonizing even the most extreme alien environments; and there is evidence of fungi on Venus (and Mars).

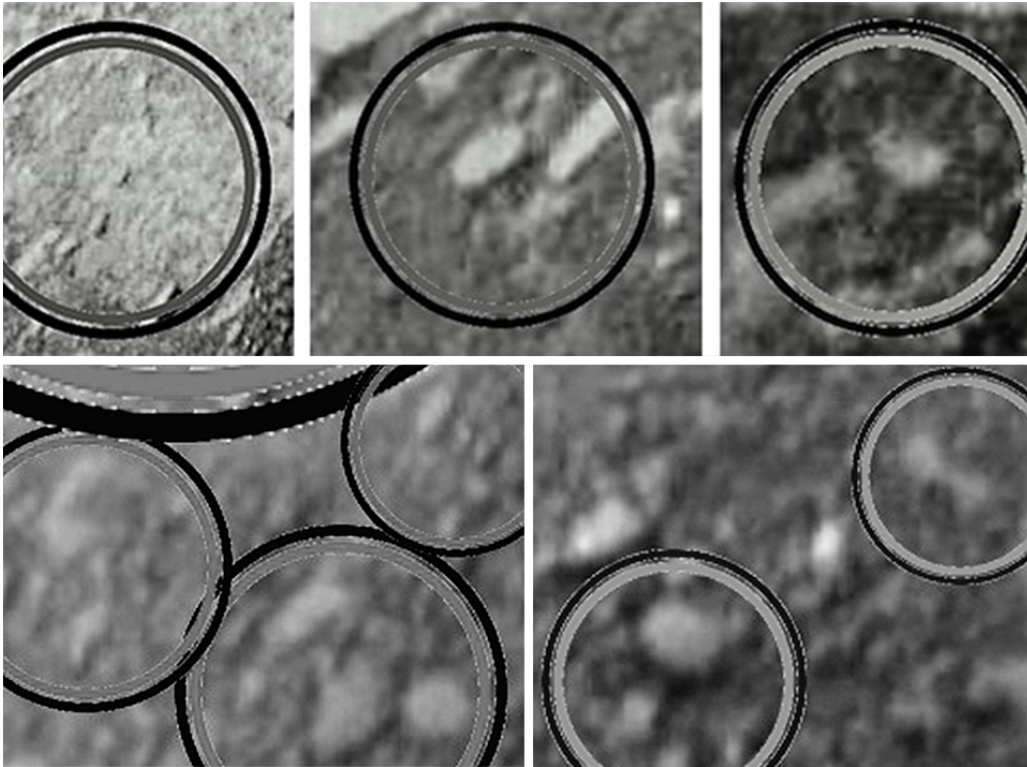
Ksanfomality (2013), based on his examination of enhanced panoramic images from the 1975 and 1982 Soviet VENERA-10, VENERA-13 and VENERA-14 images of the Venusian surface, observed what he interpreted to be a fungal-shaped specimen at a distance of 15 to 20 cm from the buffer of the landing module and which he estimated to be elevated 3 cm above the surface and with a diameter of approximately 8 cm. Ksanfomality (2013) concluded: "The object exhibits explicit similarity to terrestrial mushrooms and is supplied with folded caps."

Examination of panoramic color images from the 1982 VENERA-13 mission, also reveals several well-defined mushroom-shaped specimens with stalks that protrude approximately 3 cm from the surface, and with caps that are approximately 5 cm in diameter, and which resemble the classic terrestrial mushroom (Joseph 2019). These mushroom-shapes are bordered by a crescent of similarly shaped specimens, all of which are similar to terrestrial mushrooms. Moreover, several of these specimens resemble what may be fungal organisms growing on Mars (Joseph *et al.* 2019, 2020b). Does this prove there is life on Venus? No.

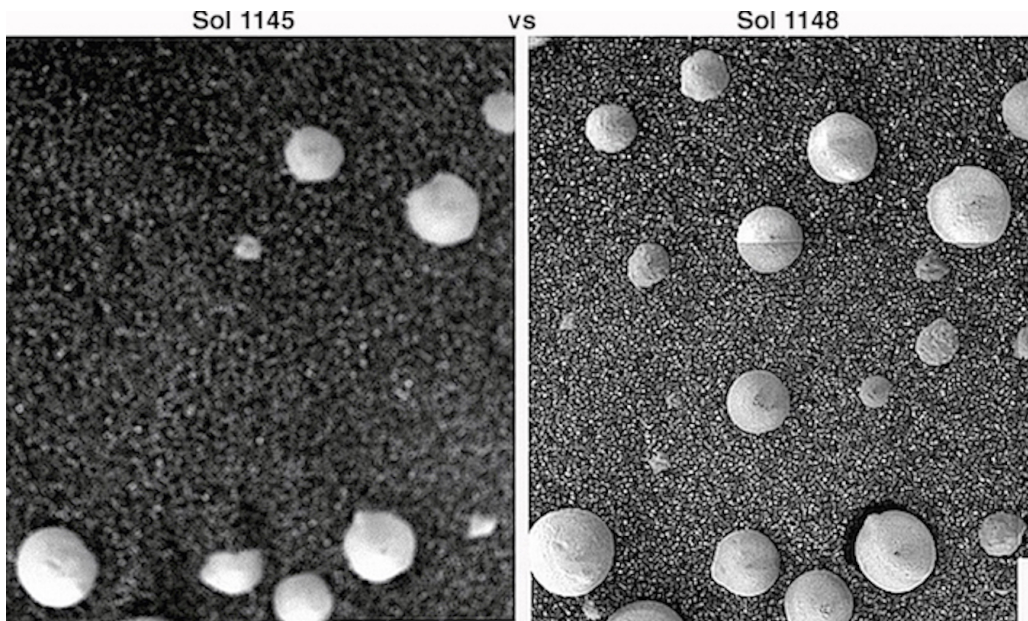
## 16 Fungi on Mars?

Several investigators have reported observations of formations on Mars that resemble white fungi growing beneath rock shelters in the dried lake bed of Gale Crater (Joseph 2014; Joseph *et al.* 2019; Rabb 2018; Small 2015). In addition, 23 specimens similar to fungal "puffballs" have been photographed by the rover Opportunity in Meridiani Planum, increasing in size over a three days period, twelve of which





**Figure 5.** Venus: Specimens resembling fungal-mushrooms. Photographed near the landing struts of the 1982 Soviet probe VENERA-13. (Reproduced with permission from Joseph 2019).



**Figure 6.** Mars. Photographed in Eagle Crater by the rover Opportunity. Comparing Sol 1145-left vs Sol 1148-right: Growth of twenty-three Martian specimens over three days, twelve of which emerged from beneath the soil and all of which increased in size. Ground level wind speeds between 40 to 70 m/h are required to move coarse grained soil on Mars, and no strong winds, dust clouds, dust devils, or other indications of strong winds were observed, photographed, or reported during those three days in this vicinity of Mars. Nor does the Sol 1148 photograph show any evidence that the surface has been disturbed by wind, as there are no parallel lineaments, ripples, waves, crests, or build-up of soil on one side of the specimens as would be expected of a directional wind. Differences in photo quality are secondary to changes in camera-closeup-focus by NASA. (Reproduced with permission from Joseph *et al.* 2020a).

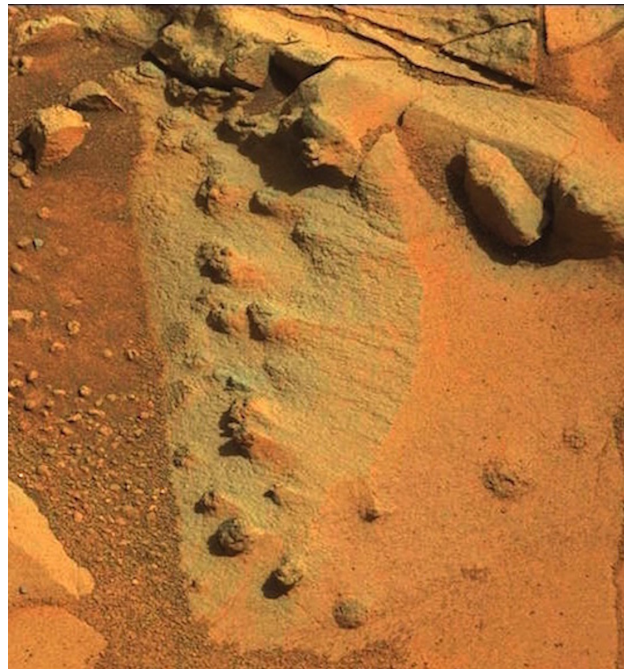


**Figure 7.** Mars. Sol 182. A majority of experts identified these specimens as basidiomycota: fungal "puffballs" (Joseph 2016). Note what appears to be spores littering the surface. (Reproduced with permission from Joseph *et al.* 2019).

emerged from beneath the coarse-grained rocky-sandy surface as based on comparisons of Sol 1145 and Sol 1148 (Joseph *et al.* 2020b) Although on Earth, 20 km/h winds can displace fine grained sand (Kidron and Zohar 2014) these specimens are buried in coarse-grained rocky soil, and no evidence of wind-blown dust in the air, dust devils, dust storms, or wind-driven soil displacement or buildup was observed in that vicinity during those three days (Joseph *et al.* 2020b). Although it is unknown if these are in fact living organisms, these observations favor the possibility that fungi have colonized Mars.

## 17 Algae and Lichens on Mars? Oxygen and Photosynthesis

Observations of what may be algae on the surface of Mars were first reported by Levin, Straat and Benton in 1978 and who observed changing patterns on "greenish rock patches" which were "green relative to the surrounding area." Levin *et al.* (1978) speculated that these greenish areas may represent "algae" or "lichens" growing on Mars.

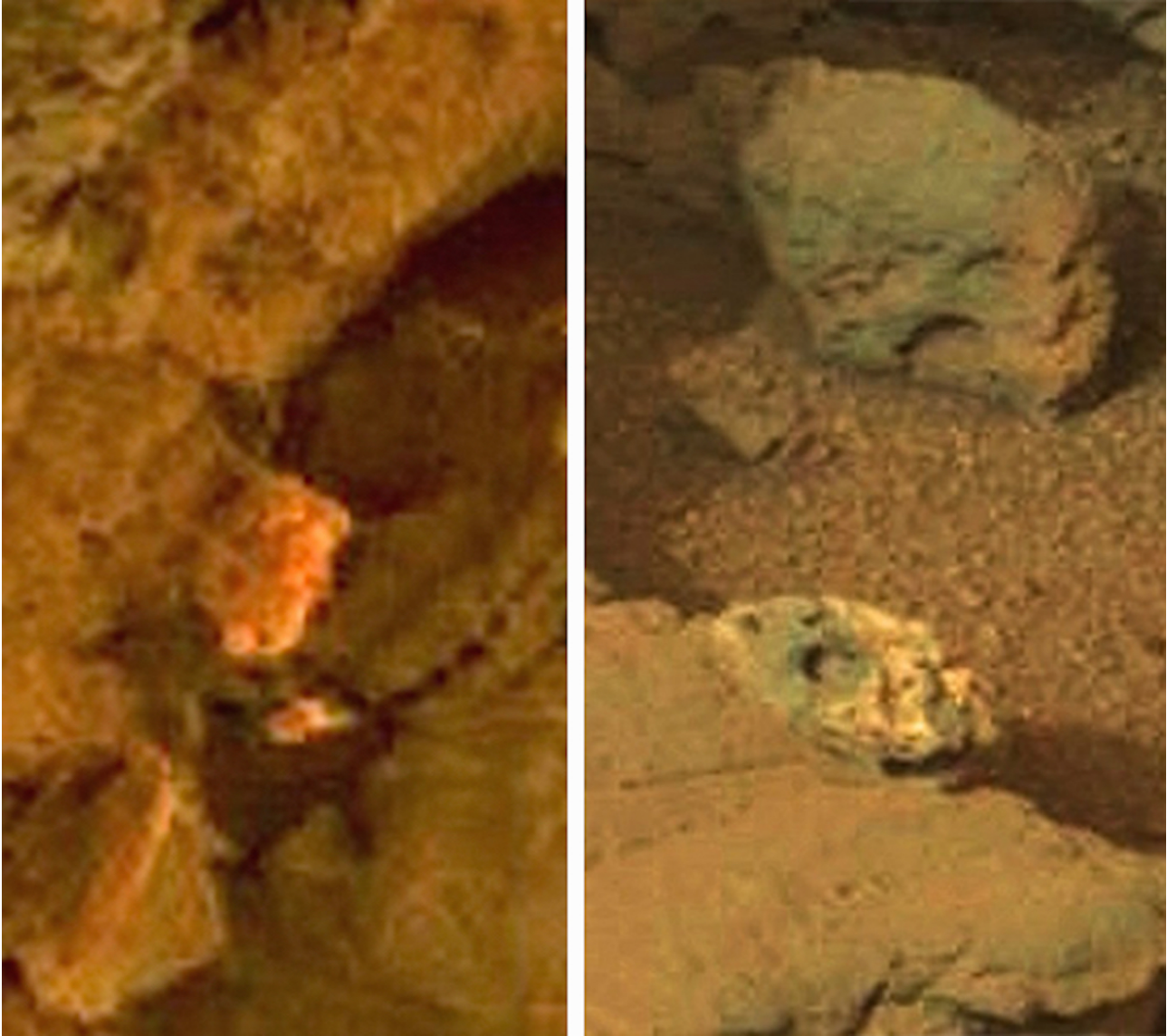


**Figure 8.** Mars. Sol 871. Green sphericals upon Martian sand, soil, rocks and pinnacle-columnar structures resembling terrestrial stromatolites and thrombolites and algae growing in shallow water, but may be frozen. On Earth, the greenish-coloration of sand and rock is due to green cryptoendolithic cyanobacteria. The darkening in soil coloration may indicate moisture. Photographed in Gale Crater. (Reproduced with permission from Joseph *et al.* 2020a).



**Figure 9.** Mars. Sol 853. Thick-layered clumps of algae-like substance and "tubular" specimens on top of and adjacent to specimens resembling fossilized bacterial mats, and adjacent to "dimpled" lichen-like organisms. Photographed in Gale Crater. (Reproduced with permission from Joseph *et al.* 2020a).

Subsequently, a number of investigators have published photos taken by the Mars rovers Spirit and Curiosity, depicting what they believed to be green algae (Joseph 2014; Joseph *et al.* 2020a; Rabb 2018; Small 2015). For example,

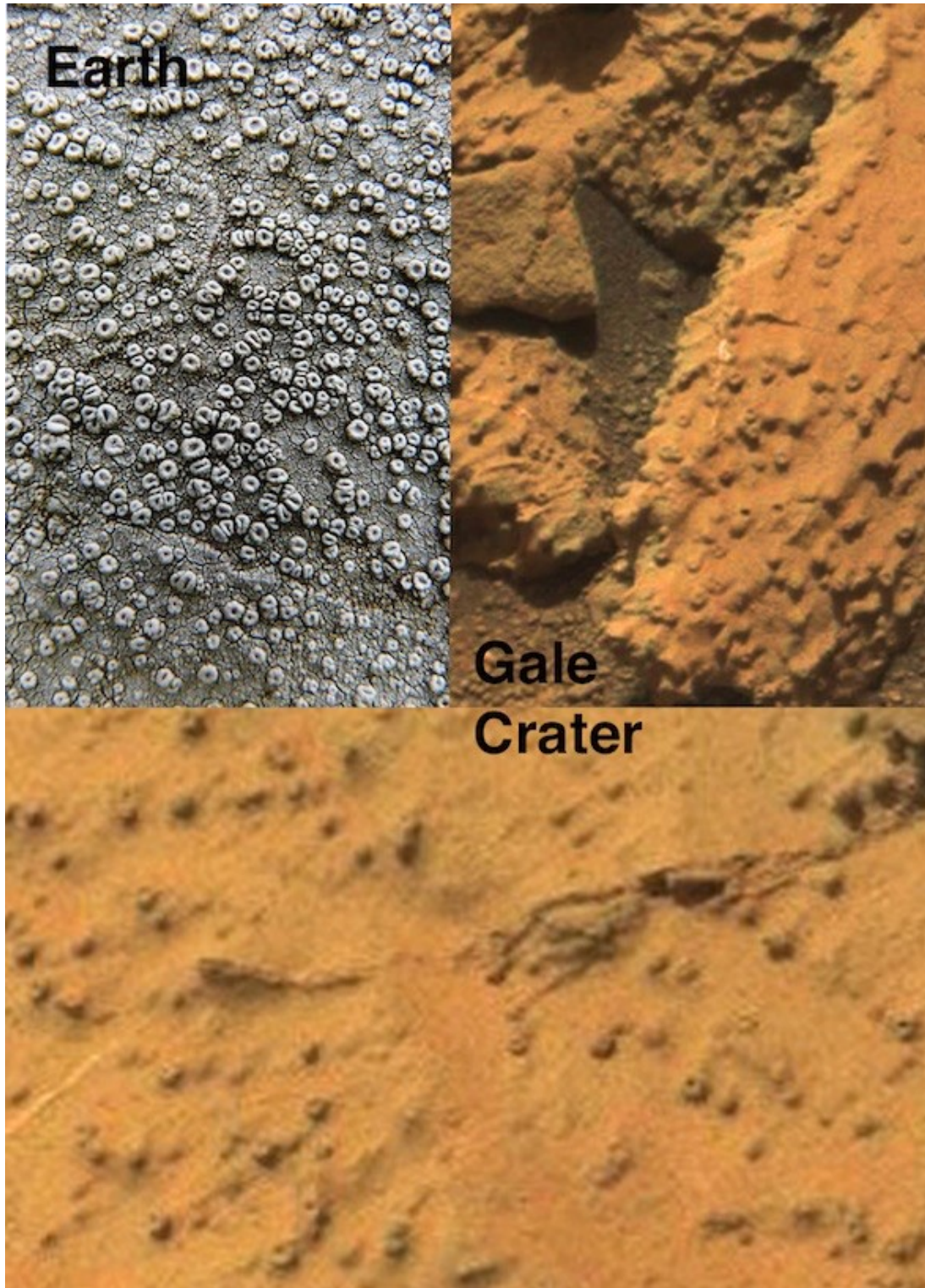


**Figure 10.** Mars. Sol 305 and Sol 305. Algae-like substances upon fungal-tubular-like specimens, and forming thin layers upon adjacent rocks. Photographed in Gale Crater. (Reproduced with permission from Joseph *et al.* 2020a).

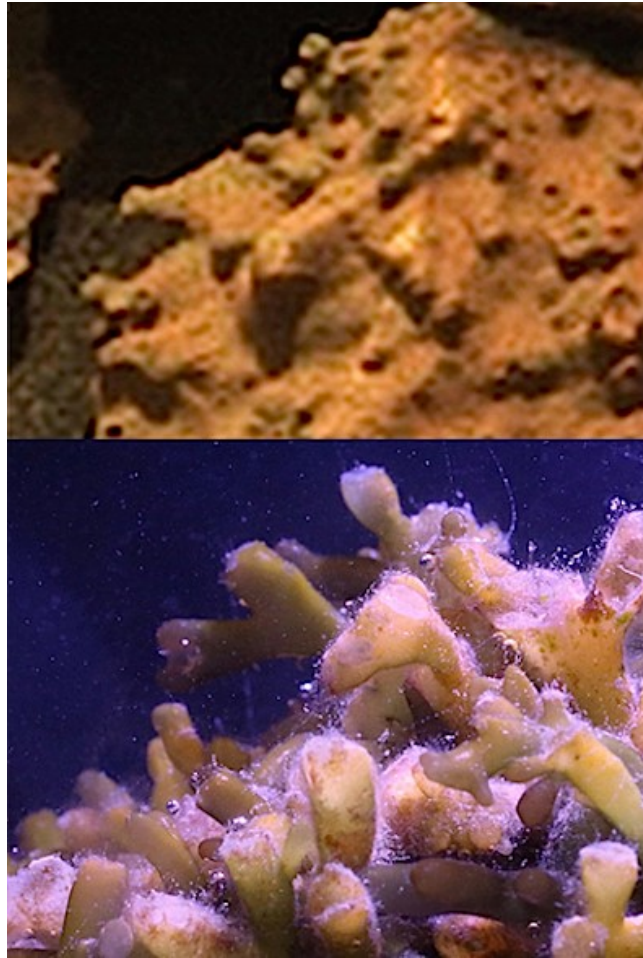
Krupa (2017) presented evidence of specimens resembling green photosynthetic organisms in the Columbia Hills area of Gusev Crater, adjacent to water pathways that may intermittently fill with water. Krupa (2017) noted that "the hillside...is covered by a very thin layer of green material" and "green spherules" which resembles algae in the soil. In addition, a team of 14 established experts conducted an extensive investigation of the Gale Crater image depository (Joseph *et al.* 2020a) and identified specimens resembling terrestrial algae and lichens. The algae-like specimens appeared as clumps and spherules, and formed cake-like layers, thin sheet-like layers and thick layered leafy vegetative masses of material that partially covered Martian rocks, sand, and fungi-like surface features.

At some point in the evolutionary history of life on Earth, algae and fungi formed a symbiotic relationship, thereby fashioning lichens. Lichens consist of at least one alga that can be a green algae or cyanobacterium (photobiont) and at least one fungus (mycobiont). The fungus is responsible for the lichens' mushroom shape, bulbous cap, thallus, and fruiting bodies, whereas the alga photobiont engages in photosynthesis (Armstrong 2017; Brodo *et al.* 2001).

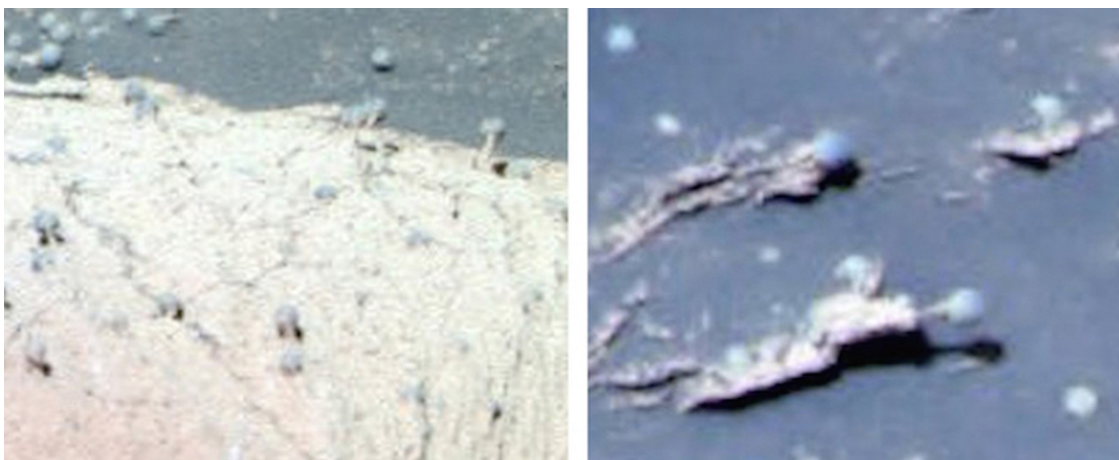
Lichen-shaped specimens observed in Gale Crater take a variety of forms, the most common: mushroom-shaped and nucleated with a visible "dimple" at the center of each specimen (Joseph *et al.* 2020a). If these are in fact living organisms, is unknown. However, hundreds of these lichen-



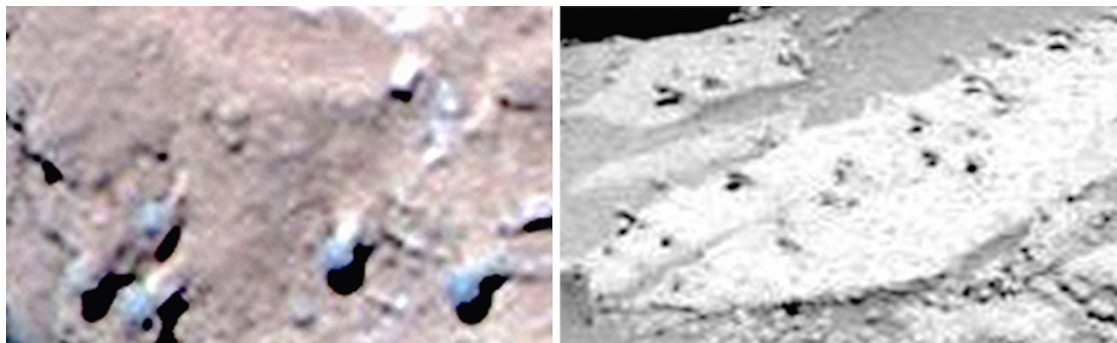
**Figure 11.** (Top Left): Earth. Lichens growing on the west coast Ireland cliffs of Moher (Photographed by Dr Jessica M Winder, <https://natureinfocus.blog>. Reproduced with permission). (Top right and bottom) Gale Crater Sol 298: Specimens resembling dimpled lichens with what may be hyphae along the surface/subsurface. Note hollow apertures in the upper right corner and lower center of photo, and which resembles an oxygen-gas vents typically produced by photosynthesizing organisms.



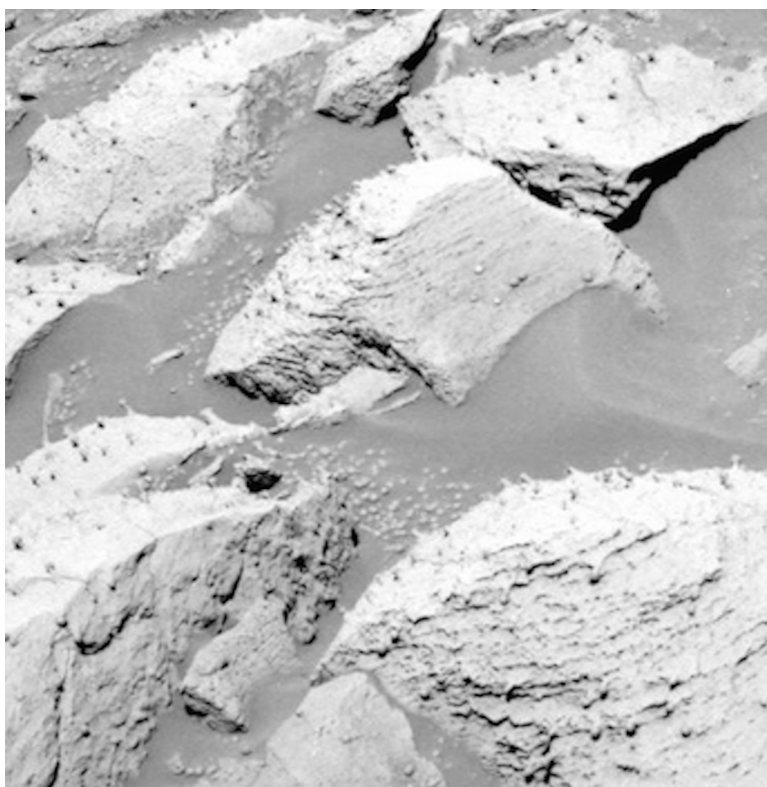
**Figure 12.** (Top) Sol 232: Specimens similar to gas-vent apertures for the release of oxygen secondary to photosynthesis within microbial mats; photographed in Gale Crater. (Bottom) Cone-like tubes for the venting of oxygen produced by photosynthesizing algae (reproduced with permission from Freeman SE, Freeman LA, Giorli G, Haas AF (2018) Photosynthesis by marine algae produces sound, contributing to the daytime soundscape on coral reefs. PLoS ONE 13(10): e0201766).



**Figure 13.** Mars. Sol 88 and Sol 37: Specimens resembling the mushroom-shaped lichen *Dibaeis baeomyces* Photographed in Eage Crater. (Reproduced with permission from Joseph *et al.* 2020b).



**Figure 14.** Mars. Sol 35 and Sol 85: Specimens resembling the mushroom-shaped lichen *Dibaeis baeomyces* and examples of colonies of lichen-shaped organisms. Photographed in Eagle Crater. (Reproduced with permission from Joseph *et al.* 2020b).



**Figure 15.** Mars. Sol 85: Examples of vast colonies of lichen-shaped organisms attached to rocks, and oriented skyward similar to photosynthesizing lichens. Photographed in Eagle Crater. (Reproduced with permission from Joseph *et al.* 2020b).

like surface features were observed adjacent to specimens resembling green algae and bubble-like open-cone apertures (Joseph *et al.* 2020a). It is well established that photosynthesizing organisms, such as cyanobacteria, respire oxygen and release gas bubbles via the surrounding matrix and which may become mineralized and fossilized as open cone apertures (Bengtson *et al.* 2009; Sallstedt *et al.* 2018). Therefore, it's possible that the open-cone apertures observed in Gale Crater serve to ventilate oxygen respired during photosynthesis.

Vast colonies consisting of thousands of lichen-mushroom-shaped specimens that resemble the lichen, *Dibaeis baeomyces*, have also been observed in Eagle Crater, attached by thin stems to the tops of rocks and oriented skyward as is typical of photosynthesizing organisms (Joseph *et al.* 2020b). Terrestrial fungi do not engage in photosynthesis; and thus, if these colonies are living photosynthesizing organisms, then they are most likely lichens.

If the algae and lichen-like Martian structures are in fact photosynthesizing organisms, this would account for the distinct seasonal variations in the oxygen content of the

atmosphere (England and Hrubec 2004) which increases by approximately 30% in the Summer, and for which no abio-genic source has been found (Trainer *et al.* 2019). Earth's atmospheric oxygen levels also vary according to the season and increase during the Spring and Summer due to the biological activity of photosynthesizing organisms; and these parallels support the likelihood that oxygen on Mars is also produced biologically, even more so since Martian atmospheric oxygen is continually replenished despite leaking into space (Joseph *et al.* 2020b).

## 18 Conclusions

In the space of the entire universe the only conclusive evidence of life is found on Earth. Although the ultimate source of all life is unknown, many investigators believe Earth, Mars, and Venus may have been seeded with life before and after becoming established members of this solar system. In support of that hypothesis is evidence, but no proof, that life appeared, in parallel on Mars and Earth 4.2 by and that stromatolites were being constructed on both planets 3.7 bya. Moreover, there is evidence, but no proof, that life on Mars may have evolved as suggested by the fossil-like specimens resembling metazoans. There is also evidence—but no conclusive proof—that fungi have colonized Mars and Venus, and algae and lichens are flourishing on Mars. By contrast, only the moon appears to be completely uninhabitable and uninhabited—other than by dormant spores—at least on the surface.

It must be stressed that it is unknown if the surface features observed on Mars and Venus are abiotic, fossils, or represent living organisms. Confirmation requires direct examination, extraction and microscopic analysis. Nevertheless, although there is no definitive, conclusive proof of life except on Earth, the evidence reviewed in this report, supports the hypothesis that the planets of the inner solar system may have repeatedly exchanged living organisms beginning billions of years ago, and that Earth may be seeding the solar system with life.

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