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SPECULATIVE POSSIBILITIES AND IMPORTANCE OF EXISTENCE OF EXTRATERRESTRIAL LIFE ON ASTRONOMICAL BODIES: AN ASTROBIOLOGY REVIEW

RASHID RASOOL RABBANI ISMAILI[a], OWAIS MAQBOOL RABBANI ISMAILI[b], SUGRA ANAM[c], TAANLOUMI[d], AMEEN LAQSAM[e], SAMEERA GHAZAL[f] AND SAADUZ ZAFAR ALI[g1]

[a]Department of Ecology and Nature Conservation, Beijing forestry University, Beijing, China
[b]Shaikh-Ul-Hind Maulana Mahmood Hasan Medical College, Saharanpur, U.P., India
[c]Department of Physics, Satavahana University, Telangana, India
[d]Department of Soil and Water Conservation, Beijing forestry University, Beijing, China
[e]Department of Mechanical Engineering, Dalian Jiaotong University, Dalian, China
[fg]Department of Zoology, Shibli National College, Azamgarh, U.P., India

ABSTRACT

Astrobiology, a multidisciplinary scientific field that seeks to investigate the origin, evolution, distribution, and future of life in the cosmos. Exobiology can be thought of as a subset of astrobiology, which is a branch of research that is at the intersection of the biological, chemical, earth, and space sciences. One of the main aims of this branch of science is to discover, examine and study the extraterrestrial life. One of the most difficult scientific challenges of all time is the origin of life dilemma. In this reference the scientific perspective is that the story of life begins with the abiogenesis and further evolved biologically. But the scientists have not given any apparent statements relevant to this. Furthermore, there are no palaeoastrobiological evidences have been recorded with main reference to extraterrestrial life. Instead of this, extremophilic microbes are crucial to astrobiological research. The primary objective of this work is to create a descriptive historical review that is summarised in literatures on exobiology, astrobiology, and extraterrestrial life. Statistical data related to astrobiological research paper publications per year from 1980 to 2022 is also shown in graphical form and the data of fatalities during spaceflight and training sessions are also mentioned. And selected space missions which are related to the field of astrobiology are presented in tabular form. This paper also covers the trails of sending earthly beings to space for several experimental activities. Where we reach in result of these trails is the presence of organic compounds are found in the collected samples from the moon, mars and other space bodies. Whereas, there is no direct evidence recorded till now about any life forms that exists in any part of universe other than earth but just rumours regarding unidentified flying objects (UFO's) and aliens, a major topic of interest for science fiction lovers. This astrobiology review is a trial to illuminate the understanding of potential life beyond Earth, serving as a foundation for future studies that explore the origins, conditions, and possibilities of extraterrestrial life forms.

KEYWORDS: Astrobiology, Observational Astronomy, Extra-terrestrial Life, Extremophiles, Biosignatures

Research on life outside of the Earth started more than 2000 years ago, and the term 'astrobiology' was first put forth by the Russian astronomer Gavriil Tikhov in 1953 (Cockell, 2001). Astrobiology, a captivating and multidisciplinary field, seeks to unravel the mysteries surrounding the existence of life beyond our planet. It encompasses a rich tapestry of scientific inquiry, blending the realms of astronomy, biology, chemistry, and planetary science. As it addresses issues that have piqued human curiosity for thousands of years, astrobiological research has the potential to have far-reaching effects beyond simple scientific discovery. Briot asserts that the notion that life existing on other planets or in other parts of the universe is connected to the issue of the multiplicity of worlds and likely originated with Greek philosophers (Briot, 2012). The term 'singularists' refers to scientists who support the idea that humans are the only technologically advanced intelligent life form in the entire milky way, making us unique in the universe. The 'pluralists', on the other hand, are in favour of the variety of planets that are home to intelligent life, or the plurality of worlds (Barcelos, 1999). The weak and strong versions of the anthropic principle discuss the existence and distribution of life and/or intelligent beings (Hawking, 1998). The idea of extraterrestrial life, particularly the prospect of it, deeply divided the ancients of Greece and Rome. The theories of Epicurus (341–270 B.C.), Democritus (460–370 B.C.), and Leucippus (born in the 5th century B.C.) are generally credited as the foundation of pluralism (Nascimento-Dias & Martinez-Frias, 2023). Exobiology, a term coined by molecular scientist and Nobel Prize winner Joshua Lederberg, is the study of the

[1]**Corresponding author**

possibility of existence of life in space or on other planets. The development of rocket technology was a factor in the field's emergence in the 1950s and 1960s. Exobiology can be described as a subset of astrobiology, where astrobiology is a field that stands at the intersection of a Venn diagram whose sets comprise chemistry, biology, earth and space sciences. Recent advances in astronomy, planetary sciences, geosciences, and microbiology have given it new life (Cockell, 2015; Sundarasami *et al.,* 2019). Extraterrestrial life, the concept of life beyond Earth, has intrigued humanity for centuries. While there is yet to be any definitive evidence of alien life, ongoing scientific research and astronomical observations continue to fuel the quest for answers (Seager, 2013). The vastness of the universe and the staggering number of galaxies, stars, and planets it contains suggest that the probability of life beyond Earth is not only plausible but quite likely. Astronomers have discovered thousands of exoplanets, planets that exist outside our solar system, some of which are situated in the 'habitable zone', where conditions may allow for the existence of liquid water—the key ingredient for life as we know it. Moreover, the discovery of extremophiles, organisms that thrive in extreme environments on Earth, has expanded our understanding of the possible forms life may take in the cosmos (Thombre *et al.,* 2020). Extremophile microorganisms are those that can survive in harsh environments when other life is thought to be impossible (Sundarasami *et al.,* 2019). Extremophiles can be divided into a variety of classes, each of which reflects how its environmental niche differs from mesophilic conditions. These divisions are not mutually exclusive. Extremophiles that fit into several different categories are referred to as polyextremophiles. Extremophiles are primarily categorised according to their capacity to endure a variety of harsh environmental circumstances, including temperature, pressure, pH, etc (Merino *et al.,* 2019; Rothschild & Mancinelli, 2001). We can better comprehend the likelihood of life on other planets that may have similar conditions by studying extremophilic creatures, their habitats, and their capacity to thrive in harsh environments (Nascimento-Dias & Martinez-Frias, 2023; Thombre *et al.,* 2020). Along with the extremophiles, the findings of organic matters on other planetary objects is considered as a positive sign towards the search result of astrobiological trails. The energy needed to form or break a bond with carbon, the fourth most common element in the universe, is just right for creating molecules that are both reactive and stable. Building incredibly long and complex molecules are made possible by the ease with which carbon atoms connect to one another. As a result, astrobiological research assumes that all life on Earth and a large proportion of living things rely on carbon chemistry (Pace, 2001). Organic material is known to be present in the materials that would have come from astronomical bodies. An extensive range of organic molecules that were produced abiotically and were accessible for delivery to planetary surfaces have been revealed, particularly through examination of carbonaceous chondrite meteorites. Amino acids, carboxylic acids, polyhydroxylated chemicals, and nucleobases are a few of these substances that are relevant to biological systems (Pearson *et al.,* 2002; Sephton, 2002; Zega *et al.,* 2010). Along with the philosophical principles and hypothetical postulates, probabilistic arguments such as principle of mediocrity and rare earth hypothesis, and Drake equation etc. Scientists are also exploring the celestial bodies and performing experiments under both government and non-government organisations. The findings of Chandrayaan-1 related to lunar water, Chang'e 4 lunar lander tests on seeds and insect eggs, researches on samples brought back by Apollo 11, observation of web building behaviour of Spider (*Araneus diadematus*) in space by Skylab 3 and many other experiments that has been done either in the search of extraterrestrial life or in support of it, for which many times various species of animals and plants were used, all show the experimental trials of scientists, researchers and astronauts supported and funded by the government and non-government organisations (Bhandari & Srivastava, 2014; Liu *et al.,* 2009; Pieters *et al.,* 2009; Zschokke *et al.,* 2020). As per officials, the Astrobiology Programme budget is set up to provide the flexibility required to adapt to the dynamic, quickly evolving field of astrobiology and NASA's capacity to create missions in the hunt for extraterrestrial life. The approximate annual budget for the Astrobiology Programme is 65 million dollars. This money is intended to pay for related research projects as well as research proposals that have been chosen from the research & analysis programmes. NASA has been funding SETI-related projects at a rate of 1.5 to 2,000,000 dollars per year since it eventually received approval from the US Congress in 1982 (Papagiannis, 1985). The 100 million dollars, ten-year Breakthrough Listen Project was introduced by Stephen Hawking and Yuri Milner in 2015. Its goal is to find signals coming from nearby stars (Worden *et al.,* 2017). For the fiscal year 2023–2024, the Indian Government has proposed allocating 12,543.91 crore rupees to the Indian Space Programme. The Department of Space (DoS), which is managed by the Indian government, will reportedly receive this amount in financing, according to Demand no. 95, Department of Space, India. In the search of life many lost their lives, by the year 2023, there had been 15 astronauts and 4 cosmonauts fatalities during spaceflight that had either crossed or was meant to cross the American definition of the outer space limit of 50 miles above the earth's surface (David, 2000; Musgrave *et al.,* 2009). This review article is focused on the published research papers, books, reports and official news reports related to the topic of Astrobiology, Exobiology, Extraterrestrial life, and Biosignatures. Herein, we also review the background of presence of organic materials and extremophiles in space other than earth and it's atmosphere. We cover the number of publications per year data from 1980 to 2022 with the forecast analysis up to 2040. Finally, we conclude the results related to the possibility of presence of extraterrestrial life on astronomical bodies.

METHODS

We used the Google Scholar (www.scholar.google.com) search engine with the keywords 'Extraterrestrial life', 'Astrobiology', 'Exobiology', 'Life on Moon', and 'Life on Mars' to find relevant citations from 1980 to 2022.

We only looked for works that offered information about the existence of life on astronomical bodies, or that documented the clues for the same such as findings related to organic matters on moon, mars or other celestial bodies and discovery of water on the land of moon and mars. We limited our search to published materials (n = 87) that met the search parameters and were published in reputable journals or books. Unpublished theses, conference proceedings, and articles in the popular press were excluded.

We subsequently identified a subset (n = 23) of the published items found in the first step that were expressly about the Astrobiology (as demonstrated by a mention of astrobiology in the title and/or a strong study focus on astrobiology described in the text). We were only interested in astrobiological studies, so papers on astronomy and astrophysics were excluded. Furthermore, we did not include papers on astrochemistry , but we did consider studies on organic matters with the exobiology focus, if they were linked. We collected the data related to the moon missions and mars missions from various official websites of space studies organisations, after reading the published literatures available in the form of research paper, review paper, meeting report, conference report, official news report and so forth.

RESULTS

Statistical Spotlight on published materials on the topic of Astrobiology and Allied Subjects

Published materials play a pivotal role in enhancing the trajectory of future astrobiological research. These resources act as beacons of accumulated knowledge, offering insights that help guide researchers towards more informed and effective investigations. By delving into peer-reviewed articles and scientific literatures, astrobiologists gain access to established theories, methodologies, and experimental techniques, enabling them to build upon a solid foundation. Furthermore, published materials highlight existing gaps in understanding, prompting researchers to formulate innovative questions and hypotheses that drive progress. These materials also serve as cautionary guides, sharing challenges and limitations encountered by others, thereby enabling researchers to anticipate obstacles and refine their approaches. Ultimately, the synergy between published insights and ongoing research efforts empowers astrobiologists to make meaningful contributions, shape new directions, and continuously refine their quests to unravel the mysteries of life beyond our planet.

The exact number of research articles published on the topic of astrobiology is vast and continually growing. This interdisciplinary field has seen a surge of interest and research efforts from scientists around the world, encompassing a wide range of subjects such as exoplanet habitability, extremophiles on earth, the origins of life, planetary exploration, and more. Thousands of research articles have been published in prestigious scientific journals, conference proceedings, and online platforms, contributing to our understanding of the potential for life beyond earth and the broader implications of such discoveries.

According to the statistics, there have been published documents with the keywords "Life on Moon", "Extraterrestrial life", "Life on Mars", "Astrobiology", and "Exobiology" totalling 2351730, 750640, 730410, 81749, and 13940 respectively. The graphical representation of elementary figures shows the highest peak in year 2014 with the value 134000 and it is for 'Life on Moon' keyword and for the same lowest peak is observed in year 1990 with the value 7700, and it shows a sharp decline in the time period of 2017 to 2022, with the decrease in value from 133000 to 73500 (Figure 1). The highest peak for 'Life on Mars' keyword is observed in year 2019 with value 35600 and the lowest peak is in year 1980 with the value 2910. The calculated 'Exponential

Regression (y)' for the data of keyword 'Life on Moon' is $5809.3e^{0.0807x}$. Comparison result for the keywords 'Life on Moon' and 'Life on Mars' is 52% as their respective percentage are 76% and 24%. Furthermore, the exponential forecast values shows a slight increase of 1% in the publications mentioning the keyword 'Life on Moon'. And the similar results are obtained from the data related to moon and mars space missions of past and present which is 73% and 27 % for current missions of moon and mars respectively, while for the future missions it is 70% and 30% for moon and mars mission, respectively, which shows 3% increase in mars space missions. The data of spaceflight-related fatalities shows that there have been total 30 fatalities, out of which 3 fatalities occurred above the Kármán line, 16 occurred below the Kármán line, and 11 happened during the training or testing.

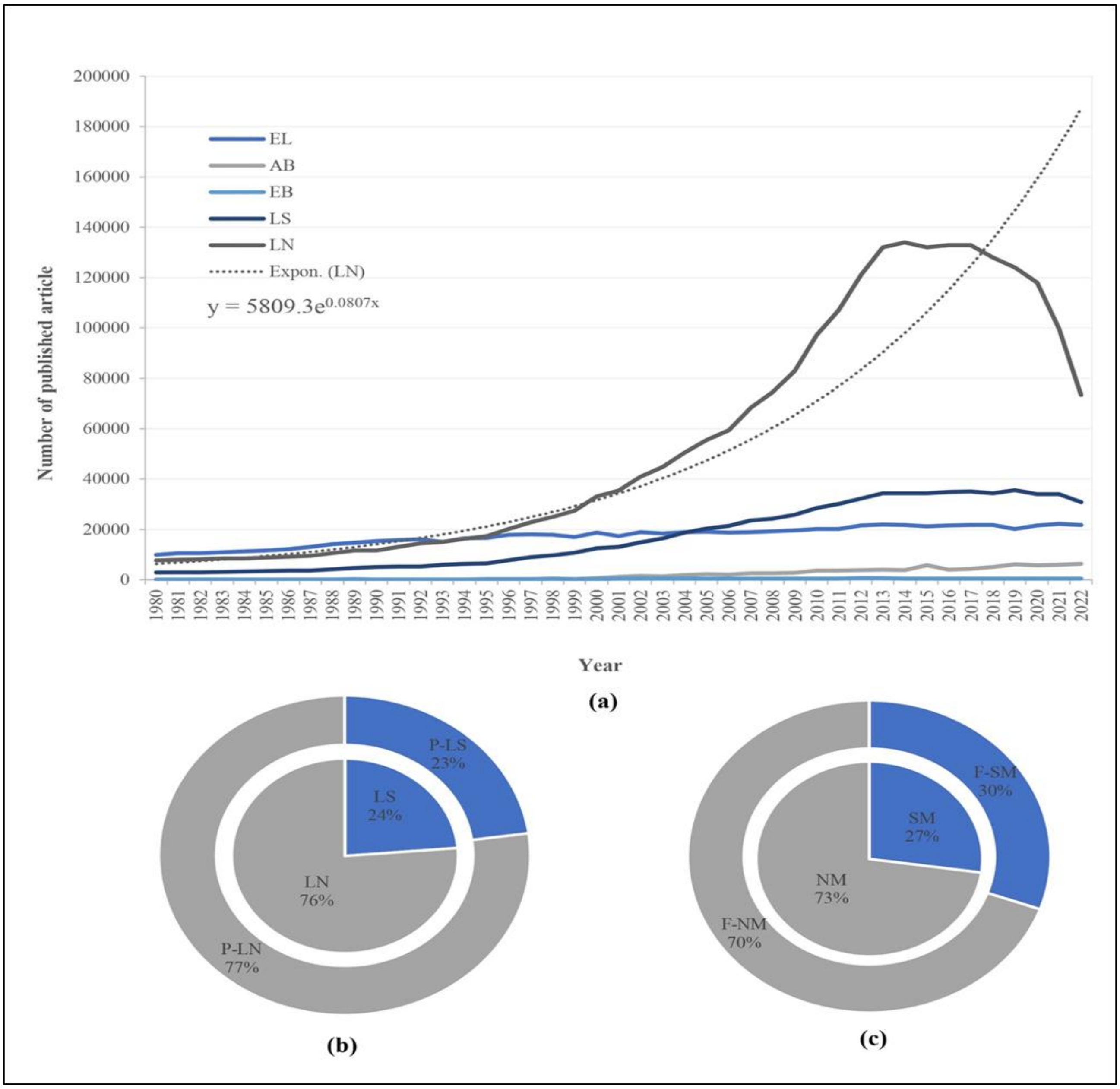

Figure 1: (a) Number of publication per year from 1980 to 2022, here LN is showing the highest peak in graph and EB the lowest peak. (b) Inner pie chart; comparative chart between the publications with keywords “Life on Moon” and “Life on Mars” shows that the publications related to Moon is 76% while it is just 24% for Mars. Outer pie chart; the forecast results of publications with keywords “Life on Moon” and “Life on Mars” from 2023 to 2040 shows 1% increase in publications related to the topic of Moon and vice-versa. (c) Inner pie chart; Comparative chart between the number of moon missions (NM) and number of mars missions (SM) shows the similar pattern of difference of 46% between moon and mars space missions, as in figure 1 (b) of life on moon and mars, which shows the difference of 52%. Outer pie chart; result of comparison between future moon and mars space missions. Abbreviations and keywords used in graph: Extraterrestrial life (EL), Astrobiology (AB), Exobiology (EB), Life on Moon (LN), Life on Mars (LS), Predicted value of life on Moon (P-LN), Predicted value of life on Mars (P-LS), Moon space mission (NM), Mars space mission (SM), Future moon space mission (F-NM), Future mars space missions (F-SM)

The Universe Genesis

In the field of astrobiology, the study of life in the universe, understanding the origins of the cosmos is crucial to unravelling the mysteries of life's existence. The most popular argument regarding the origin of the universe is the Big Bang Theory. It is also called Expanding Universe Hypothesis (Linde *et al.,* 1994; Rubakov & Gorbunov, 2018). Edwin Hubble, in 1920, provide evidence that universe is expanding, according to this theory, the universe began approximately 13.8 billion years ago from a singularity—an infinitely small and dense point (Sharov & Novikov, 1993). At this moment, an unimaginably powerful explosion occurred, giving birth to the expanding universe we observe today. Einstein's general theory of relativity has laid the theoretical groundwork for a century of advancement in our knowledge of the universe's evolution (Grøn & Hervik, 2007). There are several other hypotheses proposed related to origin and evolution of universe, one of which is creationist view of origin of universe which holds the believe that this universe is created then evolved physically and biologically, instead of its self-origination (Sciences, 1999).

Provenance of Our Solar System and the Earth

A solar system forms when a small area of a nebula—little by the standards of the universe, that is—begins to collapse upon itself. It is unclear exactly how this begins, though it may be brought on by the violent behaviour of neighbouring stars as they go through their life cycles (Encrenaz *et al.,* 2013). It is possible that the gas and dust in nearby regions of the nebula will be compressed by the energy and matter emitted by these stars. Small particles known as 'planetesimals' that were present in the solar nebula that gave rise to the sun and planets, formed from the accretion process, are likely to have contributed to the formation of the terrestrial planet, earth. Gravity brought these planetesimals together to create larger bodies, which then collided to form even larger bodies (Woolfson, 2000). Modern scientific techniques can be used to determine the ages of the universe, the milky way, the solar system, and earth. The observed correlation between the velocities and separations of galaxies can be used to calculate the age of the universe. Calculating the amount of time needed for the observed lead isotopes in the earth's oldest lead ores yield the most accurate age estimations for the planet earth. According to these calculations, the solar system and earth together have a 4.54 billion year age (Sciences, 1999).

The Outset of Life on Earth

The last phase in the evolution of the earth relates to the origin and evolution of life. It is undoubtedly clear that initially the earth or even the atmosphere of the earth was not conducive for the development of life. Modern scientists refer to the origin of life as a kind of chemical reaction, which first generated complex organic molecules and assembled them. This assemblage was such that they could duplicate themselves converting inanimate matter into living substance. The record of life that existed on this planet in different periods is found in rocks in the form of fossils and suggested that the life on earth emerged prior to 3.7 Ga (Rosing, 1999). The summary of evolution of life from unicellular bacteria to the modern man is given in the Geological Time Scale. Minute and mostly featureless, the earliest known animals are represented as fossilised tiny rod-like objects that are exceedingly difficult to distinguish from abiotic physical formations. The earliest conclusive proof of life on earth, believed to be fossilised bacteria, dates back to 3 Ga (Brasier *et al.,* 2006; Pearce *et al.,* 2018).

Rudimentary Hypotheses of Abiogenesis

According to the panspermia hypothesis, life is present throughout the universe and is spread via space dust, planetoids, asteroids, comets, and meteoroids as well as by spacecraft that unintentionally carry microbial contamination (Berera, 2017; Madhusoodanan, 2014). As per this fringe theory, when planets and small bodies in the solar system collide, debris that are blasted into space may include microscopic lifeforms that can withstand the impacts of space, such as extremophiles.

The superseded scientific theory, spontaneous generation claimed that living things might develop from inanimate objects and that such occurrences were frequent and regular. A debunked scientific idea known as spontaneous generation claimed that living things might develop from inanimate objects and that such occurrences were frequent and regular. It was proposed that some forms, like fleas, may develop from inanimate substances like dust or that maggots could develop from decomposing flesh (Crawford & Schramm, 1982).

The hypothesised set of circumstances that existed on the earth between 3.7 and 4.0 billion years ago is referred to as primordial soup or prebiotic soup. It relates to the heterotrophic theory in some way. According to Oparin, the earliest organic molecules were created by a reaction between hydrogen, carbon, ammonia, and water vapours in the early earth's surface layers. When the "Miller-Urey experiment" employed a substantially reduced mixture of gases—methane, ammonia, and hydrogen—to generate basic organic monomers like amino acids, it gave the idea of a primordial soup more credibility.

Life on the Moon

For centuries, the moon has captivated our imagination as a barren and desolate celestial body. However, recent scientific advancements and lunar exploration missions have sparked intriguing questions regarding the potential for life on our nearest neighbour. While the moon's harsh environment and lack of an atmosphere present significant challenges, researchers are actively investigating the possibility of habitability and the existence of lunar life forms (Benn, 2001).

The Lunatic Circumstance/Environment

The moon's surface is characterized by extreme temperatures, ranging from scorching hot during lunar daytime to bitterly cold during the long lunar night. Additionally, its lack of a substantial atmosphere exposes the surface to intense radiation and micrometeorite bombardment. These factors make it seem inhospitable to life as we know it. Nevertheless, the presence of certain elements and resources on the moon, such as water ice in shadowed regions near the poles, has sparked hope for potential habitability (Vaniman *et al.,* 1991).

Water on the Moon

Recent discoveries of water ice on the moon have revolutionized our understanding of lunar habitability (Table 1). Previously, scientists believed the moon to be completely devoid of water. However, the presence of water molecules, detected in permanently shadowed regions using data from orbiting spacecraft and confirmed by the impact of NASA's LCROSS probe, has opened new possibilities. Water is a fundamental requirement for life on earth, and its presence on the moon raises intriguing questions about the potential for microbial life or the potential for supporting human exploration and colonization (Robinson & Taylor, 2014) Chandrayaan-1, a spacecraft that entered lunar orbit on November 8, 2008, played a key role in the finding of water on the moon and its suite of instruments included NASA's imaging spectrometer—Moon Minerology Mapper (M3), that supported the finding of water trapped in lunar minerals (Spudis *et al.,* 2010).

Lunar Volatiles and Organic Compounds

In addition to water, ongoing research has unveiled the presence of other volatile compounds and organic molecules on the moon. These compounds, such as carbon, nitrogen, and hydrogen, are essential building blocks of life as we know it. The origins of these compounds, whether they are indigenous to the moon or delivered by comets and meteorites, are still being investigated. Their detection adds to the growing body of evidence suggesting the moon may harbour the necessary ingredients for life or provide clues about the origin and evolution of life in the solar system (Thomas-Keprta *et al.,* 2014).

Moon as a Platform for Research

Beyond the search for life itself, the Moon presents a unique opportunity for scientific research and exploration. Its geology, untouched by weathering processes, preserves a record of the early solar system and planetary evolution. Lunar craters and basins offer windows into the moon's geological history, and studying them could provide insights into earth's early history as well. Moreover, the Moon's low gravity and proximity to Earth make it an ideal testing ground for technologies and systems required for future space exploration missions to more distant destinations (Foing, 1996).

Future Lunar Missions

To address the lingering question of lunar habitability and the existence of life, several upcoming missions aim to explore the moon in greater detail. The Artemis program, led by NASA, plans to send astronauts back to the lunar surface by 2024, enabling on-site research and sample return missions. Additionally, international partners, such as the European Space Agency (ESA) and China National Space Administration (CNSA), have their own lunar exploration missions planned. These missions will provide a wealth of new data and insights into the moon's potential for hosting life (Wedler *et al.,* 2021).

Life on Mars

Mars, the fourth planet from the Sun, has long captured our curiosity and imagination as a potential abode for extra-terrestrial life. While the quest for life on mars remains ongoing, scientific advancements and the accumulation of data from past and current missions have provided intriguing insights into the planet's past habitability and the possibility of microbial life (Table 1). This article delves into the latest findings and ongoing exploration efforts that fuel the search for life on mars (Joseph *et al.,* 2019; Mckay, 1997).

Evidence from various Mars missions suggests that the Red Planet had a more habitable environment in the past. mars once possessed liquid water, as demonstrated by the presence of ancient riverbeds, deltas, and minerals that form in the presence of water. These geological features indicate that mars may have had conditions conducive to the emergence and sustenance of microbial life billions of years ago (Bishop *et al.,* 2013). NASA's rovers and landers have played a crucial role in our exploration of mars. The Pathfinder mission in 1997 paved the way for subsequent missions, including the Spirit and Opportunity rovers, which operated for years, providing invaluable data on mars' geology, atmosphere, and potential habitability. The Curiosity rover, launched in 2011, and the recently deployed Perseverance rover have advanced our understanding of mars' ancient environment and the search for signs of past life. The presence of water is a key factor in assessing a planet's habitability. Mars missions have revealed substantial evidence of water on the planet. The Phoenix lander directly observed water ice at the Martian poles, while orbiting spacecraft like the Mars Reconnaissance Orbiter have detected hydrated minerals and evidence of subsurface ice. Water is a crucial ingredient for life as we know it, and its presence enhances the potential for past or present microbial life on mars (Diez, 2018).

Table 1: Chronologically ordered list of selected space missions of 2000s and 2010s with main focus on Astrobiology

S. No.	Space Mission	Year	Launch Site	Significant Keywords	References
1	Mars Odyssey	2001	Cape Canaveral SLC-17A	Chemical elements, minerals	(Saunders *et al.,* 2004)
2	STS-107	2003	Kennedy LC-39A	*Caenorhabditis elegans,* ant colony, spiders, carpenter bees, medaka fish, silkworm	(Jules *et al.,* 2005)
3	Spitzer Space Telescope	2003	Cape Canaveral SLC-17B	Habitable zone, liquid water, organic molecules	(Firestone, 2006)
4	Mars Exploration Rover – A (Spirit)	2003	Cape Canaveral SLC-17A	Life conductive environment, past environment, geology, liquid water	(Haskin *et al.,* 2005)
5	Mars Exploration Rover – B (Opportunity)	2003	Cape Canaveral SLC-17B	Life conductive environment, past environment, geology, liquid water	(Arvidson *et al.,* 2011)
6	Mars Reconnaissance Orbiter	2005	Cape Canaveral SLC-41	Habitable environment, water	(Zurek & Smrekar, 2007)
7	Genesis I	2006	Dombarovsky, Russia	Madagascan hissing cockroaches, Mexican jumping beans	(Seedhouse, 2015)
8	Genesis II	2007	Dombarovsky, Russia	Madagascar hissing cockroach, South African flat rock scorpion, *Hadogenes troglodytes*, seed-harvester ants, *Pogonomyrmex californicus,*	(Seedhouse, 2015)
9	FOTON-M3	2007	Baikonur, Kazakhstan	Eutardigrade, *Paramacrobiotus richtersi*, *Macrobiotus richtersi*, tardigrade, Tardigrade Resistance to Space Effects	(Rebecchi, Altiero, Cesari, Bertolani, *et al.,* 2011; Rebecchi *et al.,* 2009)
10	Chandrayaan-1	2008	Satish Dhawan Second Pad	Lunar water-ice, lunar water, chemical and mineralogical mapping	(Pieters *et al.,* 2009)
11	EXPOSE	2008	Unclear*	Irradiation studies, origin of life, evolution of life, distribution of life	(Wassmann *et al.,* 2012)
12	Kepler space telescope	2009	Cape Canaveral SLC-17B	Habitable zone, Earth-size planet	(Savanov & Dmitrienko, 2011)
12	STS-129	2009	Kennedy LC-39A	Microbe, Microbial-1 experiment, *Escherichia coli*, *Bacillus subtilis*, Painted Lady butterfly, *Vanessa cardui*, Monarch butterfly, *Danaus plexippus*, Advanced Biological Research System (ABRS), Advanced Plant Experiments on ISS — Cambium (APEX-Cambium), *Caenorhabditis elegans*	(Cox *et al.,* 2010; Higashitani *et al.,* 2009; Moreno *et al.,* 2012)

13	O/OREOS	2010	Kodiak, LP-1	*Bacillus subtilis,* Spore Germination, Nanosatellites, microorganism, space stress	(Nicholson & Ricco, 2019)
14	STS-134	2011	Kennedy LC-39A	TARDIKISS project, Tardigrades, *Paramacrobiotus richtersi*, *Ramazzottius oberhaeuseri*	(Rebecchi, Altiero, Cesari, Marchior, *et al.,* 2011)
16	Curiosity Mars Rover	2011	Cape Canaveral SLC-41	Capable environments, microbial life, climate and geology, lakes, groundwater, fatty acid	(WilliamsAmy *et al.,* 2019)
17	Kavoshgar Class C (Pishgam)	2013	Unclear*	Aftab, rhesus monkey, monkey, primate,	(Tarikhi, 2015)
18	Foton-M4	2014	Baikonur 31/6	Thick-toed gecko, *Chondrodactylus turneri*,	(Gulimova *et al.,* 2019)
19	SpaceX CRS-4	2014	Cape Canaveral, SLC-40	Mice, bone densitometer, osteoporosis, rodent research	(Roberts, 2014)
20	SpaceX CRS-6	2015	Cape Canaveral, SLC-40	C57BL/6, mice, muscle loss, rodent research	(Roberts, 2014)
21	SpaceX CRS-8	2016	Cape Canaveral SLC-40	Myostatin inhibition, muscle atrophy, mice, rodent research, human endothelial cell, automated cell culture	(Imura *et al.,* 2018; Pietsch *et al.,* 2017)
22	Chang'e 4	2018	Xichang Satellite Launch Center, LA-2	*Arabidopsis thaliana*, Cotton, potato seeds, fruit-fly eggs, yeast	(Jones, 2019)
23	Chandrayaan-2	2019	Satish Dhawan Space Centre Second Launch Pad	Lunar water-ice, lunar water, chemical and mineralogical mapping	(Pieters *et al.,* 2009)

The detection of methane in atmosphere of mars has sparked excitement among scientists. Methane can be produced by both biological and geological processes, making it a potential biomarker for life. Observations from orbiting spacecraft and the Curiosity rover have revealed varying levels of methane, including localized plumes. Additionally, the discovery of complex organic compounds in Martian rocks further strengthens the case for mars' potential habitability and the existence of past or present life (Ten Kate, 2018). The ongoing mars missions, particularly the Perseverance rover, are aimed at studying mars' geology and collecting samples for future return to earth. These carefully selected samples will undergo extensive analysis in laboratories on earth, allowing scientists to search for definitive signs of past microbial life. This ambitious endeavour will provide unprecedented insights into mars' potential for habitability and the existence of extra-terrestrial life (Green *et al.,* 2017; Taylor, 2009).

Life on Other Planets

Exploration tactics have been devised recently to pursue astrobiological goals for these objects. Investigating the amount and distribution of organic chemicals and biomolecules, as well as the ambient conditions, as these are vital in the search for biosignatures, are the main scientific goals of current and future space missions to these bodies and to find signs of early biota, as well as to find out if there are any native species now present somewhere on the surface or beneath these planetary bodies. Other than mars and moon of earth there are several celestial objects such as Titan, Europa, Venus, Enceladus; which have drawn the attention of space organisations more and more due to their biological potential for hosting both present and extinct life, as well as the fact that they provide realistic examples of how life could have emerged independently of earth evolution (Kanik & Paul de Vera, 2021).

Venus is a valuable resource for examining the variety, evolution, and possible habitability of terrestrial exoplanets because it is our closest neighbour. It might help us understand how a planet changed from being a habitable greenhouse world to one with a surface environment that seems uninhabitable (Kane *et al.,* 2019). Venus is a very appealing destination for short-term astrobiological study due to its proximity to earth, guidance for planetary habitability investigations, access to the putative cloud habitable layer, and surface for extended in situ extended observations. The finding that Venus' atmosphere was significantly more abundant in deuterium than in hydrogen, compared to Earth's atmosphere, indicated that venus formerly had a surface covering of water that was at least 0.3% by volume of an earthly ocean and probably considerably more. Cockell (1999) evaluated the potential habitability of the existing Venusian cloud layer and determined that it was suitable for terrestrial microbial-type life. The cloud layers between 48 and 70 km above venus' surface feature temperatures and pressures of 750 K and 93 bar, which resemble the characteristics of microorganisms having clouds on earth. Venus should undoubtedly be of scientific interest to astrobiologists in order to better understand the beginnings of life in general (Limaye *et al.,* 2021).

Europa and Enceladus, two ocean worlds coated in ice, have, nevertheless, more lately emerged as promising research destinations for astronomers. Enceladus is a top option for a mission to look for extraterrestrial life in the following ten years since measurements made by the Cassini spacecraft have already shown enough evidence that the ocean there is habitable. The case for Enceladus' and Europa's oceans' capacity to harbour past or present life is strengthened by evidence for continuing hydrothermal activity on Enceladus and prospective hydrothermal activity on Europa that is similar to that observed on Earth's Atlantic Ocean floor. Europa is Jupiter's second-largest moon. Under Europa's frozen surface, salty oceans have been found by the Galileo probe, which was intended to explore Jupiter and its moons. The discovery of hydrated sodium carbonates helped to clarify the existence of alkaline waters on Europa. Oceans that are saline have water activity a_w of 0.6e1 (Marion *et al.,* 2003). The Saturn's Moon, Enceladus, is well known for frequently ejecting ice plumes into space. 99% of the solids ejected from these plumes are thought to be salt-rich ice particles, with a smaller percentage of these particles making it into Saturn's E ring. This raises the likelihood of halophilic life existing on Saturn's moon, which strengthens the need for further research into the ability of halophilic microbes to endure harsh environments (Hsu *et al.,* 2015).

The Cassini-Huygens mission demonstrated that Titan, the only moon in our Solar System recognised to possess a dense atmosphere, is an extraordinary place. Titan is frigid and far from the Sun, yet solar radiation interacts with its methane-rich atmosphere to cause the production of complex organic compounds and erosols, which eventually settle on Titan's surface and may trigger other chemical reactions. Additionally, liquid water brought to the surface from Titan's ocean by cryovolcanic activity may hint at the potential of habitation, if not directly on the surface due to the extremely frigid surface temperatures, then nearby in the subsurface (Kanik & Paul de Vera, 2021).

Importance of Astrobiology

In General

The importance of astrobiology lies in its potential to address fundamental questions about our place in the cosmos and to expand our understanding of life and its potential throughout the universe. Below are some key reasons why astrobiology is significant: By studying the conditions under which life emerged on earth, astrobiologists can gain insights into the processes and environments that may have given rise to life elsewhere in the universe. This could shed light on the likelihood of finding life beyond earth. Astrobiology's primary goal is to search for signs of life beyond earth. The discovery of even microbial life on other celestial bodies, such as mars or some of the moons of jupiter and saturn, would be a ground-breaking revelation with profound implications for humanity. The study of extreme environments on earth, such as hydrothermal vents, acidic lakes, and frozen tundras, helps astrobiologists identify potential habitable zones on other planets and moons. Understanding habitability criteria enhances the search for life beyond our planet. Astrobiology is crucial in guiding planetary protection protocols to avoid contaminating other celestial bodies with terrestrial life during space missions. It ensures the integrity of potential extraterrestrial habitats and preserves scientific purity in sample collection. The discovery of extraterrestrial life could fundamentally change our perspective on our place in the universe, our understanding of life's diversity, and our societal and philosophical outlooks. Astrobiology is an interdisciplinary field that brings together scientists from various disciplines and nations to work towards common goals, fostering international collaboration and cooperation (Cockell *et al.,* 2016; Des Marais *et al.,* 2008).

Economic Perspective

Astrobiology research plays a vital role in the search for life on other planets and moons, driving the development of space missions and technologies. This, in turn, stimulates the space industry, leading to job creation and economic growth. The discovery of habitable exoplanets and potential biosignatures can generate interest in future interstellar missions and space-based observatories, contributing to the growth of space exploration companies and organizations (Summers & Trefil, 2017). Astrobiology research involves studying extremophiles, organisms adapted to extreme environments. Knowledge gained from this research can have applications in biotechnology, leading to the development of new drugs, enzymes, and bio-inspired materials. Discovering extraterrestrial life or its potential building blocks could have profound implications for our understanding of life's origins and evolution. This knowledge may inspire breakthroughs in medicine, biochemistry, and genetics (Cockell, 2020). The pursuit of astrobiology and the possibility of discovering life beyond earth can generate public interests in space exploration and astronomy. Increased public engagement may lead to greater support for space agencies and private space companies, stimulating growth in the space tourism sector. Astrobiology and space-related educational programs can inspire the next generation of scientists, engineers, and space enthusiasts, fostering human capital development and potential contributions to various industries (Ehrenfreund *et al.,* 2006; Reid, 2006).

CONCLUSION

Exploratory astronomy in recent decades has made it possible to find hospitable place on other planets that support life. In addition to exoplanets, research into the environment on the early earth, where early life is thought to have emerged, has always been popular. Exobiology may help us comprehend these settings better. Extremophiles offer a viable area for exobiology research because of their adaptability to conditions that would be harmful to other creatures. There is an entire spectrum of possibilities for life on other planets. A planet may be lifeless and lack any vestiges of organic matter and/or palaeoastrobiological record in the form of fossils. Alternatively, it may be lifeless but contain organic matter and/or palaeoastrobiological record in the form of fossils. There may be life having simple or quite complex biochemistry, physiology, and behaviour. Even intelligent life with a technical civilization may be found. Confirmation of any of these possibilities would be of great scientific importance.

Extending the branches of the phylogenetic tree, which will reveal more precise information about the beginning of life in the cosmos and tie it to economic values, is the result of investing billions and trillions of dollars on astrobiology missions. If scientists are able to obtain any current palaeoastrobiological proof of extraterrestrial life in the form of biological fossils, it may be possible. Even if many economic activities (such as space tourism and the mining of the moon and asteroids for economically useful resources) will likely be conducted for solely commercial ends, science will nonetheless stand to gain significantly from this development. In fact, science will gain from every stage of the 'bootstrapping' of a space economy, from the early exploration of the Moon and asteroids through the use of the resources obtained to further space activity.

Future lunar resource utilisation is becoming more popular, both as a means of funding lunar exploration and as a way to boost the space economy. There are many of raw resources on the moon that could be economically valuable for human activities in the future, especially those that take place in space. It is true that, given what is known at this time, it is challenging to pinpoint a single lunar resource that is likely to be valuable enough to support an industry focused on extracting lunar resources in the short term. There are other extraterrestrial raw material sources that could aid in the growth of such a space-based economy besides the moon. Derivatization agents used in Martian missions may contain complicated chemical molecules that should be handled with caution. It is less likely that the original organic material will be altered or contaminated as a result of the measurements themselves when non-destructive methods are used, for example the Raman and fluorescence spectroscopy currently utilised by Perseverance and the Raman and infrared spectroscopy combined with laser desorption techniques that will be used by the future ExoMars mission (Ansari, 2023).

Ultimately, it was feasible to draw the conclusion that, despite the fact that astrobiology is a relatively new field of study in science, the idea of looking for life beyond earth existed long before the advent of modern science. With the advancement of technology many spaceflights have been sent in the search of extraterrestrial life and billions of dollars have been used, many lost their lives. In the more distant future, the creation of interstellar probes for the investigation of planets surrounding neighbouring stars may be a significant scientific advantage of a well-developed space infrastructure (Crawford, 2016). However, the paucity of evidence thus far should not be interpreted as proof that there is no life elsewhere in the universe. According to Fry (2015), it is wise to consider the repercussions of discovering living beings, whether in microbial, complex, or intelligent form, before having discovered traces of extraterrestrial life or understanding if there is intelligent life or not. And as per the footage released by NASA on official portal, it says "No signs of life were even found in the lunar samples. The research paved the way for later work in astrobiology and the search for life on mars". Despite the fact that majority of publications, space missions, experimental studies for the search of existence of life have only been conducted on the moon and its samples. In conclusion, even if extraterrestrial life is never found, this mobilisation of the various agents and their domains greatly adds to the cosmic social view that is required in light of the present unrest and our future.

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REFERENCES

Ansari A.H., 2023. Detection of organic matter on Mars, results from various Mars missions, challenges, and future strategy: A review. Frontiers in Astronomy and Space Sciences, **10**: 1075052.

Arvidson R.E., Ashley J.W., Bell J.F., Chojnacki M., Cohen J., Economou T.E., Farrand W.H., Fergason R., Fleischer I., Geissler P., Gellert R., Golombek M.P., Grotzinger J.P., Guinness E.A., Haberle R.M., Herkenhoff K.E., Herman J.A., Iagnemma K.D., Jolliff B.L., Johnson J.R., Klingelhöfer G., Knoll A.H., Knudson A.T., Li R., McLennan S.M., Mittlefehldt D.W., Morris R.V., Parker T.J., Rice M.S., Schröder C., Soderblom L.A., Squyres S.W., Sullivan R.J. and Wolff M.J., 2011. Opportunity Mars Rover mission: Overview and selected results from Purgatory ripple to traverses to Endeavour crater. Journal of Geophysical Research: Planets, **116**(E7). https://doi.org/https://doi.org/10.1029/2010JE003746

Barcelos E., 1999. The hot soup: a brief history of theories about the origin of life and extraterrestrial life (1920–1959). Revista Múltipla, Brasília **4**: 9-20.

Benn C., 2001. The moon and the origin of life. Earth-Moon Relationships: Proceedings of the Conference held in Padova, Italy at the Accademia Galileiana di Scienze Lettere ed Arti, November 8–10, 2000,

Berera A., 2017. Space dust collisions as a planetary escape mechanism. Astrobiology, **17**(12): 1274-1282.

Bhandari N. and Srivastava N., 2014. Active moon: evidences from Chandrayaan-1 and the proposed Indian missions. Geoscience Letters, **1**(1): 11. https://doi.org/10.1186/s40562-014-0011-y

Bishop J.L., Loizeau D., McKeown N.K., Saper L., Dyar, M.D., Des Marais D.J., Parente M. and Murchie, S.L., 2013. What the ancient phyllosilicates at Mawrth Vallis can tell us about possible habitability on early Mars. Planetary and Space Science, **86**: 130-149.

Brasier M., McLoughlin N., Green O. and Wacey D., 2006. A fresh look at the fossil evidence for early Archaean cellular life. Philosophical Transactions of the Royal Society B: Biological Sciences, **361**(1470): 887-902. https://doi.org/doi:10.1098/rstb.2006.1835

Briot D., 2012. A possible first use of the word astrobiology? Astrobiology, **12**(12): 1154-1156. https://doi.org/10.1089/ast.2012.0896

Cockell C.S., 2015. Astrobiology: understanding life in the Universe. (1 ed.). New Jersey: John Wiley & Sons.

Cockell C.S., 2001. 'Astrobiology' and the ethics of new science. Interdisciplinary Science Reviews, **26**(2): 90-96. https://doi.org/10.1179/isr.2001.26.2.90

Cockell C.S., 2020. Astrobiology: understanding life in the universe. John Wiley & Sons.

Cockell C.S., Bush T., Bryce C., Direito S., Fox-Powell M., Harrison J.P., Lammer H., Landenmark H., Martin-Torres J. and Nicholson N., 2016. Habitability: a review. Astrobiology, **16**(1): 89-117.

Cox D.R., Murdoch T., Regan M., Meshlberger R., Mortenson T., Albino S., Paul A. and Ferl R., 2010. Biological Imaging Capability in the ABRS Facility on ISS.

Crawford I.A., 2016. The long-term scientific benefits of a space economy. Space Policy, **37**: 58-61. https://doi.org/https://doi.org/10.1016/j.spacepol.2016.07.003

Crawford M. and Schramm D.N., 1982. Spontaneous generation of density perturbations in the early universe. Nature, **298**(5874): 538-540.

David S., 2000. Disasters and accidents in manned spaceflight. Springer Science & Business Media.

Des Marais D.J., Nuth J.A., Allamandola L.J., Boss A.P., Farmer J.D., Hoehler T.M., Jakosky B.M., Meadows V.S., Pohorille A. and Runnegar B., 2008. The NASA astrobiology roadmap. Astrobiology, **8**(4): 715-730.

Diez A., 2018. Liquid water on Mars. Science, **361**(6401): 448-449.

Ehrenfreund P., Irvine W., Owen T., Becker L., Blank J., Brucato J., Colangeli L., Derenne S., Dutrey A. and Despois D., 2006. Astrobiology: future perspectives (Vol. 305). Springer Science & Business Media.

Encrenaz T., Bibring J.-P., Blanc M., Barucci M.-A., Roques F. and Zarka P., 2013. The solar system. Springer Science & Business Media.

Firestone M., 2006. Astrobiologist. Infobase Publishing.

Foing B., 1996. The Moon as a platform for astronomy and space science. Advances in Space Research, **18**(11): 17-23.

Green J., Hollingsworth J., Brain D., Airapetian V., Pulkkinen A., Dong C. and Bamford R., 2017. A future Mars environment for science and exploration. Planetary science vision 2050 workshop,

Grøn O. and Hervik S., 2007. Einstein's general theory of relativity: with modern applications in cosmology. Springer Science & Business Media.

Grotzinger J.P., Crisp J., Vasavada A.R., Anderson R.C., Baker C.J., Barry R., Blake D.F., Conrad P., Edgett K.S. and Ferdowski B., 2012. Mars Science Laboratory mission and science investigation. Space Science Reviews, **170**: 5-56.

Gulimova V., Proshchina A., Kharlamova A., Krivova Y., Barabanov V., Berdiev R., Asadchikov V., Buzmakov A., Zolotov D. and Saveliev S., 2019. Reptiles in space missions: Results and perspectives. International Journal of Molecular Sciences, **20**(12): 3019.

Haskin L.A., Wang A., Jolliff B.L., McSween H.Y., Clark B.C., Des Marais D.J., McLennan S.M., Tosca N.J., Hurowitz J.A. and Farmer J.D., 2005. Water alteration of rocks and soils on Mars at the Spirit rover site in Gusev crater. Nature, **436**(7047): 66-69.

Hawking S., 1998. A Brief History of Time. Bantam Books. https://books.google.co.in/books?id=cF37wAEACAAJ

Higashitani A., Hashizume T., Sugimoto T., Mori C., Nemoto K., Etheridge T., Higashitani N., Takanami T., Suzuki H. and Fukui K., 2009. C. elegans RNAi space experiment (CERISE) in Japanese Experiment Module KIBO. Biological Sciences in Space, **23**(4): 183-187.

Hsu H.-W., Postberg F., Sekine Y., Shibuya T., Kempf S., Horányi M., Juhász A., Altobelli N., Suzuki K. and Masaki Y., 2015. Ongoing hydrothermal activities within Enceladus. Nature, **519**(7542): 207-210.

Imura T., Nakagawa K., Kawahara Y. and Yuge L., 2018. Stem cell culture in microgravity and its application in cell-based therapy. Stem cells and development, **27**(18): 1298-1302.

Jones A., 2019. China grew two leaves on the moon: The Chang'e-4 spacecraft also carried potato seeds and fruit-fly eggs to the lunar far side-(News). IEEE Spectrum, **56**(11): 9-10.

Joseph R.G., Dass R.S., Rizzo V., Cantasano N. and Bianciardi G., 2019. Evidence of life on Mars. Journal of Astrobiology and Space Science Reviews, **1**: 40-81.

Jules K., Hrovat K., Kelly E. and Reckhart T., 2005. STS-107 Microgravity Environment Summary Report.

Kane S.R., Arney G., Crisp D., Domagal□Goldman S., Glaze L.S., Goldblatt C., Grinspoon D., Head J. W., Lenardic A. and Unterborn C., 2019. Venus as a laboratory for exoplanetary science. Journal of Geophysical Research: Planets, **124**(8): 2015-2028.

Kanik I. and Paul de Vera J.-P., 2021. Editorial: Astrobiology of Mars, Europa, Titan and Enceladus - Most Likely Places for Alien Life [Editorial]. Frontiers in Astronomy and Space Sciences, **8**. https://doi.org/10.3389/fspas.2021.643268

Limaye S.S., Mogul R., Baines K.H., Bullock M.A., Cockell C., Cutts J.A., Gentry D.M., Grinspoon D.H., Head J.W. and Jessup K.-L., 2021. Venus, an astrobiology target. Astrobiology, **21**(10): 1163-1185.

Linde A., Linde D. and Mezhlumian A., 1994. From the Big Bang theory to the theory of a stationary universe. Physical Review D., **49**(4): 1783.

Liu L., Guo H., Zhao L., Wang J., Gu J. and Zhao S., 2009. Achievements and perspectives of crop space breeding in China. Induced plant mutations in the genomics era, pp. 213-215.

Madhusoodanan J., 2014. Microbial stowaways to Mars identified. Nature. https://doi.org/10.1038/nature.2014.15249

Marion G.M., Fritsen C.H., Eicken H. and Payne M.C., 2003. The search for life on Europa: limiting environmental factors, potential habitats, and Earth analogues. Astrobiology, **3**(4): 785-811.

Mckay C.P., 1997. The search for life on Mars. Origins of Life and Evolution of the Biosphere, **27**: 263-289.

Merino N., Aronson H.S., Bojanova D.P., Feyhl-Buska J., Wong M.L., Zhang S. and Giovannelli D., 2019. Living at the Extremes: Extremophiles and the Limits of Life in a Planetary Context. Front Microbiol, **10**: 780. https://doi.org/10.3389/fmicb.2019.00780

Moreno N., Vogt G. and Thomson W., 2012. Butterflies in Space. 49th AIAA Aerospace Sciences Meeting including the New Horizons Forum and Aerospace Exposition,

Musgrave G.E., Larsen A. and Sgobba T., 2009. Safety design for space systems. Butterworth-Heinemann.

Nascimento-Dias B.L.d. and Martinez-Frias J., 2023. Brief review about history of astrobiology. International Journal of Astrobiology, **22**(1): 67-78. https://doi.org/10.1017/S1473550422000386

Nicholson W.L. and Ricco A.J., 2019. Nanosatellites for biology in space: in situ measurement of Bacillus subtilis spore germination and growth after 6 months in low earth orbit on the O/OREOS mission. Life, **10**(1): 1.

Pace N.R., 2001. The universal nature of biochemistry. Proceedings of the National Academy of Sciences, **98**(3): 805-808. https://doi.org/doi:10.1073/pnas.98.3.805

Papagiannis M.D., 1985. A Historical Introduction to the Search for Extraterrestrial Life. The Search for Extraterrestrial Life: Recent Developments, Dordrecht.

Pearce B.K., Tupper A.S., Pudritz R.E. and Higgs P.G., 2018. Constraining the time interval for the origin of life on Earth. Astrobiology, **18**(3): 343-364.

Pearson V.K., Sephton M.A., Kearsley A.T., Bland P.A., Franchi I.A. and Gilmour I., 2002. Clay mineral-organic matter relationships in the early solar system. Meteoritics & Planetary Science, **37**(12): 1829-1833. https://doi.org/https://doi.org/10.1111/j.1945-5100.2002.tb01166.x

Pieters C.M., Goswami J.N., Clark R.N., Annadurai M., Boardman J., Buratti B., Combe J.-P., Dyar M.D., Green R., Head J.W., Hibbitts C., Hicks M., Isaacson P., Klima R., Kramer G., Kumar S., Livo E., Lundeen S., Malaret E., McCord T., Mustard J., Nettles J., Petro N., Runyon C., Staid M., Sunshine J., Taylor L.A., Tompkins S. and Varanasi P., 2009. Character and spatial distribution of OH/H2O on the surface of the Moon seen by M3 on Chandrayaan-1. Science, 326(5952), 568-572. https://doi.org/doi:10.1126/science.1178658

Pietsch J., Gass S., Nebuloni S., Echegoyen D., Riwaldt S., Baake C., Bauer J., Corydon T.J., Egli M., Infanger M. and Grimm D., 2017. Three-dimensional growth of human endothelial cells in an automated cell culture experiment container during the SpaceX CRS-8 ISS space mission – The SPHEROIDS project. Biomaterials, **124**: 126-156. https://doi.org/https://doi.org/10.1016/j.biomaterials.2017.02.005

Rebecchi L., Altiero T., Cesari M., Bertolani R., Rizzo A. M., Corsetto P.A. and Guidetti R., 2011. Resistance of the anhydrobiotic eutardigrade Paramacrobiotus richtersi to space flight (LIFE–TARSE mission on FOTON□M3). Journal of Zoological Systematics and Evolutionary Research, **49**: 98-103.

Rebecchi L., Altiero T., Cesari M., Marchior T., Giovannini I., Rizzo A., Ganga P., Vikich M., Donati A. and Zolesi V., 2011. TARDIKISS: tardigrades in the mission STS-134, the last of the shuttle Endeavour.

Rebecchi L., Altiero T., Guidetti R., Cesari M., Bertolani R., Negroni M. and Rizzo A.M., 2009. Tardigrade resistance to space effects: first results of experiments on the LIFE-TARSE mission on FOTON-M3 (September 2007). Astrobiology, **9**(6): 581-591.

Reid I.N., 2006. Astrobiology: A Multidisciplinary Approach. Physics Today, **59**(12): 58-58. https://doi.org/10.1063/1.2435684

Roberts M.S., 2014. Of mice and men: Rodent habitats in space have become essential to understanding human diseases on earth. IEEE pulse, **5**(4): 42-45.

Robinson K.L. and Taylor G.J., 2014. Heterogeneous distribution of water in the Moon. Nature Geoscience, **7**(6): 401-408.

Rosing M.T., 1999. 13C-depleted carbon microparticles in 3700-Ma sea-floor sedimentary rocks from West Greenland. Science, **283**(5402): 674-676.

Rothschild L.J. and Mancinelli R.L., 2001. Life in extreme environments. Nature, **409**(6823): 1092-1101. https://doi.org/10.1038/35059215

Rubakov V.A. and Gorbunov D.S., 2018. Introduction to the Theory of the Early Universe: Hot big bang theory. World Scientific.

Saunders R., Arvidson R., Badhwar G., Boynton W., Christensen P., Cucinotta F., Feldman W., Gibbs R., Kloss C. and Landano M., 2004. 2001 Mars Odyssey mission summary. Space Science Reviews, **110**: 1-36.

Savanov I. and Dmitrienko E., 2011. Stellar activity from observations with the KEPLER space telescope: The M dwarf GJ 1243. Astronomy Reports, **55**: 890-895.

Sciences N.A.O., 1999. Science and Creationism: A View from the National Academy of Sciences (Second Edition ed.). National Academies Press (US).

Seager S., 2013. Exoplanet Habitability. Science, **340**(6132): 577-581. https://doi.org/doi:10.1126/science.1232226

Seedhouse E., 2015. Genesis I and II. In E. Seedhouse (Ed.), Bigelow Aerospace: Colonizing Space One Module at a Time (pp. 67-85). Springer International Publishing. https://doi.org/10.1007/978-3-319-05197-0_4

Sephton M.A., 2002. Organic compounds in carbonaceous meteorites. Natural product reports, **19**(3): 292-311.

Sharov A.S. and Novikov I.D., 1993. Edwin Hubble, the discoverer of the big bang universe. Cambridge University Press.

Spudis P.D., Bussey D., Baloga S., Butler B., Carl D., Carter L.M., Chakraborty M., Elphic R., Gillis Davis J. and Goswami J., 2010. Initial results for the north pole of the Moon from Mini SAR, Chandrayaan1 mission. Geophysical Research Letters, **37**(6).

Summers M.E. and Trefil J., 2017. Exoplanets: Diamond Worlds, Super Earths, Pulsar Planets, and the New Search for Life beyond Our Solar System. Smithsonian Institution.

Sundarasami A., Sridhar A. and Mani K., 2019. Chapter 13 - Halophilic archaea as beacon for exobiology: Recent advances and future challenges. In S.N. Meena & M.M. Naik (Eds.), Advances in Biological Science Research (pp. 197-214). Academic Press. https://doi.org/https://doi.org/10.1016/B978-0-12-817497-5.00013-6

Tarikhi P., 2015. IranIan Space endeavor. Springer.

Taylor F.W., 2009. The scientific exploration of Mars. The Scientific Exploration of Mars.

Ten Kate I.L., 2018. Organic molecules on Mars. Science, **360**(6393): 1068-1069.

Thomas-Keprta K.L., Clemett S.J., Messenger S., Ross D.K., Le L., Rahman Z., McKay D.S., Gibson Jr, E.K., Gonzalez C. and Peabody W., 2014. Organic matter on the Earth's Moon. Geochimica et Cosmochimica Acta, **134**: 1-15.

Thombre R.S., Vaishampayan P.A. and Gomez F., 2020. Chapter 7 - Applications of extremophiles in astrobiology. In R. Salwan & V. Sharma (Eds.), Physiological and Biotechnological Aspects of Extremophiles (pp. 89-104). Academic Press. https://doi.org/https://doi.org/10.1016/B978-0-12-818322-9.00007-1

Vaniman D., Reedy R., Heiken G., Olhoeft G. and Mendell W., 1991. The lunar environment. The lunar Sourcebook, CUP, pp.27-60.

Wassmann M., Moeller R., Rabbow E., Panitz C., Horneck G., Reitz G., Douki T., Cadet J., Stan-Lotter H. and Cockell C.S., 2012. Survival of spores of the UV-resistant Bacillus subtilis strain MW01 after exposure to low-earth orbit and simulated martian conditions: data from the space experiment ADAPT on EXPOSE-E. Astrobiology, **12**(5): 498-507.

Wedler A., Schuster M.J., Müller M.G., Vodermayer B., Meyer L., Giubilato R., Vayugundla M., Smisek M., Dömel A. and Steidle F., 2021. German Aerospace Center's advanced robotic technology for future lunar scientific missions. Philosophical Transactions of the Royal Society A, **379**(2188): 20190574.

Williams Amy J., Beth W., Stewart J., Craft Kathleen L., Knudson Christine A., Lewis James M., Glavin Daniel P., Williams Ross H., Summons Roger E. and Mahaffy Paul R., 2019. Recovery of fatty acids from mineralogic Mars analogs by TMAH thermochemolysis for the sample analysis at mars wet chemistry experiment on the Curiosity Rover. Astrobiology.

Woolfson M.M., 2000. The origin and evolution of the solar system. CRC Press.

Worden S.P., Drew J., Siemion A., Werthimer D., DeBoer D., Croft S., MacMahon D., Lebofsky M., Isaacson H., Hickish J., Price D., Gajjar V. and Wright J.T., 2017. Breakthrough Listen – A new search for life in the universe. Acta Astronautica, **139**: 98-101. https://doi.org/https://doi.org/10.1016/j.actaastro.2017.06.008

Zega T.J., Alexander C.M.O.D., Busemann H., Nittler L. R., Hoppe P., Stroud R.M. and Young A.F., 2010. Mineral associations and character of isotopically anomalous organic material in the Tagish Lake carbonaceous chondrite. Geochimica et Cosmochimica Acta, **74**(20): 5966-5983. https://doi.org/https://doi.org/10.1016/j.gca.2010.07.018

Zschokke S., Countryman S. and Cushing P.E., 2020. Spiders in space—orb-web-related behaviour in zero gravity. The Science of Nature, **108**(1): 1. https://doi.org/10.1007/s00114-020-01708-8

Zurek R.W. and Smrekar S.E., 2007. An overview of the Mars Reconnaissance Orbiter (MRO) science mission. Journal of Geophysical Research: Planets, **112**(E5). https://doi.org/https://doi.org/10.1029/2006JE002701