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EDITORIAL

Special issue: Open questions and next steps in astrobiology in Europe – celebrating 20 years of EANA

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20 years of EANA – European Astrobiology Network Association

The European Astrobiology Network Association (EANA) aims to develop and promote astrobiology in Europe and beyond, to connect European astrobiologists, and foster their cooperation. EANA celebrated its 20th anniversary in 2021 during the annual meeting, which was hosted virtually from Porto, Portugal (Fig. 1). Further, EANA also celebrated its first two successful decades with several events (e.g., more than 270 people attended the first EANA online Intl Spring School on Hydrothermal Vents, 17–21 May 2021) consolidating its central role for astrobiology in Europe.

The idea of creating EANA germinated on 22 April 1999 at the meeting of the European Geophysical Society held in the Hague, the Netherlands. It was the brainchild of a small group of scientists, the prebiotic chemist André Brack, the space microbiologists Gerda Horneck and David Wynn-Williams, and the geologist Beda Hoffmann (Brack *et al*., 2001, 2004; Brack, 2005), and has continued to grow since the inaugural meeting of the European Exo/Astrobiology Steering Group at the British National Space Centre in London, UK, on 25–26 October 1999, and at the Strategy Oriented Meeting at CNES in Paris, France, on 18–19 October 2000. It was supported by the European Science Foundation (ESF) and the European Space Agency (ESA) recommendation to sustain and formalize a European astrobiology network.

Thanks to the tenaciousness of these passionate astrobiologists, among whom were our first two presidents, André Brack and Gerda Horneck (Fig. 2), EANA was formally initiated during the First European Workshop on Astrobiology co-organized together with ESA at European Space Research Institute in Frascati, Italy, in spring 2001.

The main objectives of the First European Workshop on Astrobiology (Brack *et al*., 2001) were, among others, to connect European astrobiologists and foster their collaborations, to assess the extent of interest and resources for astrobiology within Europe (including ESA, the European Commission, and the ESF) to attract young scientists to this research field, to generate a European astrobiology roadmap, to promote astrobiology in all European countries, including those without fully active programmes, and to encourage interaction between EANA and NASA.

Figure 1. *The EANA (left), EANA2021 20 years celebration (center), and EANA2021 conference (right) logos; the logos were designed by Katarina Eriksson, Barbara Cavalazzi, and Marta Cortesão, respectively.*

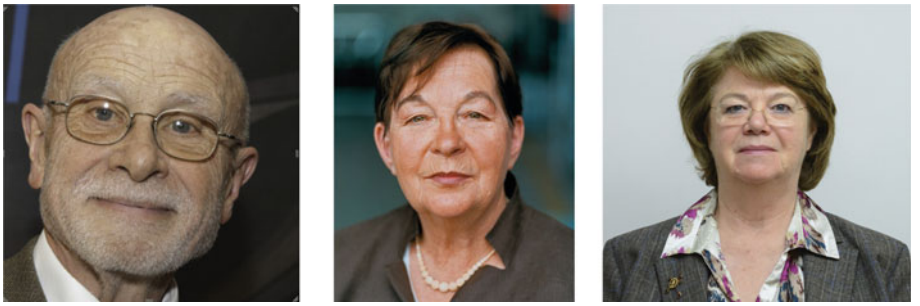

Figure 2. *Past EANA's presidents: André Brack (left), president from 2001 to 2007, Gerda Horneck (center), president from 2007 to 2013, and Frances Westall (right), president from 2013 to 2019. Thank you for your enthusiasm!*

The initial European steering group convened to formalize a network consisting of twelve countries (Table 1). Since then, the astrobiology community in Europe has steadily increased year after year; today, the community has 21 member states (20 European countries and 1 non-European country) (Table 1). In these 20 years, EANA has provided a platform and forum for the astrobiology community in Europe, organized annual meetings on astrobiology (Table 2), and remained very active in the area of education through the ABC-Net lecture courses, a live tele-teaching programme in cooperation with ESA, as well as summer and winter schools connected to several European universities (details and materials are available at http://www.eana-net.eu/). EANA was an unofficial part of the NASA-run National Astrobiology Institute (NAI), and is supported by ESA. EANA has also been continually supported by international journals, including the International Journal of Astrobiology, founded in 2002, with EANA member David Wynn-Williams as Editor in Chief (now headed by Rocco Mancinelli and the team at Cambridge University Press), Astrobiology, founded in 2001 under the guidance of Sherry L. Cady and her team at Mary Ann Liebert, Inc., publishers, and Origins of Life and Evolution of Biospheres, founded in 1968 and covering astrobiology and origins of life research, edited by EANA member Alan W. Schwartz and the team at Springer.

Stimulated by the annual EANA meetings, European early-career astrobiologists founded an independent but EANA-affiliated association called Astrobiology Graduates in Europe (AbGradE) in 2014. AbGradE organizes symposia and workshops during which, among others, scientific sessions, keynote lectures, and networking are held (Noack *et al*., 2015). In 2013, the European AstRoMap project organized a survey of the astrobiology science community in Europe and beyond, developing the first European roadmap for astrobiology research and producing a detailed profile of the European astrobiology community (Horneck *et al*., 2016). The AstRoMap Roadmap also identified major research topics

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Table 1. *Member states in 2001, when EANA was founded, and expanded list of member states in 2021*

European steering group in 2001	European steering group in 2021
Austria	Austria
Belgium	Belgium
Denmark	Czechia
France	Denmark
Germany	Finland
Italy	France
Portugal	Germany
Spain	Greece
Sweden	Hungary
Switzerland[a]	Italy
The Netherlands	Japan[a]
United Kingdom	Malta
	Poland
	Portugal
	Romania
	Russia[a]
	Spain
	Sweden
	Switzerland[a]
	The Netherlands
	United Kingdom[a]

[a]Non-EU countries.

(origin and evolution of planetary systems; origins of organic compounds in space; rock–water–carbon interactions, organic synthesis on Earth, and steps to life; life and habitability; biosignatures as facilitating life detection) and a strategy to address them. The major recommendation of the AstRoMap was the establishment and implementation of a European Astrobiology Platform to catalyse all scientific achievements in the field. Since 2001, EANA has grown year by year and its bottom-up organizational approach has supported the development of a strong sense of community among its members, which helped to ensure the continuation of the community through the COVID-19 pandemic.

The first two decades of the 21st century have seen a steady rise in the acceptance of astrobiology as a discipline with national associations being established in many of EANA's member states. The community is vibrant, inventive and ground-breaking, frequently inspiring other associations. It also continually supports and offer guidance to young researchers. EANA provides European and non-European astrobiologists with an informative interdisciplinary network, dynamic teaching and learning environment, mentorship, a venue to sustain and exchange ideas, and an opportunity to build bridges between people and institutions.

The last two decades have seen many EANA members involved in space missions, mission concepts and the development and undertaking of protocols and experiments in space. In particular, EANA members have been and continue to be active in organising experiments in low Earth orbit aboard the International Space Station, and in Mars exploration with missions to search for life such as Mars 2020 and ExoMars. The coming years are full of promise for astrobiologists and the EANA community will be actively involved.

During its lifetime, EANA has witnessed enormous leaps in our understanding of life in the universe in the broadest sense, as the contributions to this Special Issue of the International Journal of Astrobiology show. This Open Questions and Next Steps in Astrobiology in Europe – Celebrating

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Table 2. *EANA annual meetings organized since its foundation in 2001*

EANA annual meeting
EANA 2001, Frascati, Italy
EANA 2002, Graz, Austria
EANA 2003, Madrid, Spain
EANA 2004, Milton Keynes, United Kingdom
EANA 2005, Budapest, Hungary
EANA 2006, Lyon, France
EANA 2007, Turku, Finland
EANA 2008, Neuchâtel, Switzerland
EANA 2009, Brussels, Belgium
EANA 2010, Pushchino, Russia
EANA 2011, Köln, Germany
EANA 2012, Stockholm, Sweden
EANA 2013, Szczecin, Poland
EANA 2014, Edinburgh, United Kingdom
EANA 2015, Noordwijk, the Netherlands
EANA 2016, Athens, Greece
EANA 2017, Aarhus, Denmark
EANA 2018, Berlin, Germany
EANA 2019, Orléans, France
EANA 2020, EANA without borders[a]
EANA 2021, Porto, Portugal[a]

[a]Virtual mode.

20 Years of EANA Special Issue includes perspectives and historical descriptions of the European network, reviews, and research papers outlining the latest European research in astrobiology. In the following, an overview of the contributed articles is given.

Can Mars analogue microorganisms survive under Martian conditions? This is a critical question for understanding the potential of Martian organisms to survive in the harsh conditions reigning presently on the planet whether brought to the surface from deep underground reservoir or surviving a crashed (or not very clean) spacecraft. To answer this intriguing query, Beblo-Vranesevic *et al*. (2022), (Volume 21 Issue 2) have devised an experiment to expose these organisms, either as individual species or as mixtures, to simulated Martian conditions using the particular conditions found on the outside of the International Space Station. Having collected these organisms from different kinds of Mars-analogue, extreme environments on Earth, including cold sulphidic springs, deep sea brine pools, high radiation conditions combined with high salt and low temperature, these polyextremophiles comprise the MEXEM experiment (Mars Exposed Extremophiles Mixture), where selected model organisms will be subjected to space for a period of 3 months. In preparation for this mission, Beblo-Vranesevic and colleagues report on the survival of two strains *Salinisphaera shabanensis* and *Buttiauxella* sp. MASE-IM-9 exposed in the laboratory to Mars-relevant stress factors (such as desiccation and ultraviolet (UV) radiation under anoxia), noting that the survival rate doubled when the microorganisms were mixed with simulated Martian regolith, and was also increased by mixing the two strains. Such preparatory, lab-based experiments are important when preparing for the rare opportunities to use the International Space Station as experimental support.

In this letter, Nauny *et al*. (2022), (this issue) track the history of the enterprising AbGradE community comprising initially early career European scientists and, recently, encompassing non-European young scientists. Started in 2013, the group aimed at providing a physical and virtual

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meeting place where young researchers could hear state-of-the-art presentations from confirmed scientists on a broad range of topics and exchange amongst themselves in a vibrant and convivial atmosphere. AbGradE interacts with other established communities, such as EANA, the EAI, EPEC, EAC, and COST Action TD1308. The last few years of covid halted the physical encounters but the AbGradE community continued to support each other through their website, newsletter, and social media. While the lack of physical interaction was strongly felt, 'The online events Virtual AbGradE'20, Space Law and Governance'21 and Virtual AbGradE'21 have been the most attended AbGradE events with participants from more than 40 countries', as noted by Nauny and colleagues. In the future, the tools developed during the pandemic have aided interactions that will be furthered in a more convivial manner through 'nerdy pub quizzes' etc. during face-to-face meetings.

Micca Longo and Longo (2022), (this issue) applying a simulated entry model to Mars by using White Soft Minerals (WSMs) in the form of micro-grains (mimic micrometeorites), show that moderate temperature will be reached and maintained entering the Martian atmosphere with lower entry speed. The WSMs chemical/thermal decomposition process seems much slower than predicted, and this suggests both a possible transfer of organic molecules, and Mars have been a promising collector of matter in this form.

As stated in Meneghin *et al*. (2022), (this issue), even though Mars sample return missions are already planned and the NASA rover Perseverance is already preparing samples for that purpose, the procedure of dealing with those samples back on Earth is still under investigation. Several techniques have been proposed over the last decades, but a critical comparison of these methods was missing so far. In this article, the authors provide a possible way to even rank the different techniques by using the correlation matrix method. Further, it should help to determine the correlation between certain biosignatures (19 in total, divided into five categories) and the analytical techniques (18 selected techniques). The authors present their biosignatures versus technique correlation matrix based on the 2017 iMOST study and conclude that the Top 3 techniques according to their importance are LDI-MS, MALDI-TOF, and SIMS.

Mosca *et al*. (2022), (this issue) report about their studies with dry cells of the radioresistant cyanobacterium *Chroococcidiopsis* sp. CCMEE 029, where they used high-LET radiation mimicking long-term irradiation on the Martian surface. The conducted experiments should give insight about the long-term resilience against potential DNA damage of dormant microbial life in the Martian subsurface. If the DNA damage could be kept within bounds, it could be repaired in phases of more clement conditions between two states of dormancy. Mosca *et al*. demonstrate that the survival of the tested dried cyanobacterium was not significantly reduced, even though DNA damage was determined. The results and conclusions presented in this study are not only relevant for the understanding of potential life in the Martian subsurface, but also in other highly radiated environments like on the icy moons of the outer Solar System.

Longo *et al*. (2022), (this issue) analyse the biotic scenario of the selection of biological homochirality and revise the biology-grounded models of the selective extinction process highlighting the complexity of the selective extinction dynamics and the nontrivial chemical-physical concepts involved, finally presenting a new class of computer programs. Results show persistent differences between the populations of the two different chiral types and suggest a selective extinction of one of the two types based on the freedom of individual populations to fluctuate wildly while the total population is stabilized by the limited availability of chemical energy.

Cassaro *et al*. (2022), (this issue) report on studies on the effect of gamma rays on two classes of fungal biomolecules – nucleic acids and melanin pigments. Both molecules are considered unambiguous biosignature molecules for which no abiotic pathway of formation is known. Therefore, they may serve as signatures to be searched for during in-situ-life detection missions beyond the Earth. Using a series of high-resolution spectroscopic methods, Cassaro and co-workers demonstrate that these biomolecules can persist radiation doses equivalent to an exposure of 1.5 million years on the surface of Mars and of about 13 million years at 2 metres depth. In addition, they highlight that chitin may also be included in the list of robust biosignature molecules for which one could search for during life-seeking missions.

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In their research paper, Maris *et al*. (2022), (this issue) used rotational spectroscopy coupled to supersonic expansions to characterize the rotational spectrum of dimethyl sulfoxide and its ^{34}S and ^{13}C isotopologues, confirming the importance of spectroscopic methods and laboratory work to obtain unambiguous identification of spectral features of astrobiological importance such as sulphur bearing molecules, which will enable the identification and quantification of molecules in interstellar space and atmospheres of planets in the Solar Systems and of exoplanets.

Barbieri and Cavalazzi (2022), (this issue) illustrate in their research article surface biogenic micromorphologies from the Salina di Cervia (Italy) hypersaline system. This site harbours halophilic and halotolerant ecosystems, which upon their interactions with the sedimentary shallow subsurface produce several stable microstructures and morphologies. Some of these surface features (e.g. the deformation structures of thin layers of diatom frustules associated with the salt ribbons) have been proposed by the authors to be considered among potentially preservable fossil biosignatures. The authors suggest this hypersaline extreme environment as an analogue field site for Mars.

Kobayashi *et al*. (2022), (this issue) correlate phosphatase activity with other biomarkers in different regions of the Atacama Desert, which is considered a Mars analogue environment. In contrast to other biomarkers, phosphatase activity is a measure of potential metabolic activity and not a measure of presence only. The authors found that phosphatase activity is positively correlated with amino acid concentrations as well as with the number of colony-forming units and that it is negatively correlated with the amount of precipitation. Based on their observations, they conclude that phosphatase activity could act as an activity biomarker in extreme environments on the Earth and beyond.

Brack (2022), (this issue) provides his own summary of the most important factors in the emergence of life: liquid water and the necessity of some form of wet-dry cycling; organic molecules of terrestrial or extraterrestrial origin; inorganic substrates, such as clays or silica gel providing attributes, such as protection, catalysation, serving as templates, absorption etc.; a suitable environment, such as hydrothermal systems (subaqueous or subaerial); far from equilibrium wet-dry cycling reactants based on mineral surfaces in hydrothermal systems; an approach based on systems chemistry, which allows all the cellular subsystems to simultaneously emerge. He considers the two principal approaches to the emergence of life, the 'metabolism-first approach', where autotrophic life arises from the direct formation of simple molecules from CO_2, and the 'heterotrophic-first approach' in which key molecules, such as protein enzymes and RNA are formed and compartmentalized. He concludes with the caution that RNA, although an essential molecule, is too complex and too large to have formed spontaneously – the challenge lies with the next generations of prebiotic chemists to use the promising avenue of 'open wet-dry cycling organic reactions running far from equilibrium, at mineral surfaces and under hydrothermal-like conditions'.

A review by Bak *et al*. (this issue) presents a detailed analysis of the Viking lander investigations and their fresh reconsideration in the context of the challenging search for organics and biosignatures on Mars. This review is focused on abiotic alterations of organic material on Mars such as those caused by UV- and ionizing radiation and wind-driven erosion. Bak *et al*. (2022) reviewed extensively the role of physical and chemical mechanisms for the preservation of organics in the Martian surface regolith. Their comprehensive review demonstrates the difficulties for the identification of life on Mars and emphasises the crucial importance of laboratory experiments to distinguish between abiotic breakdown and biological alteration of organic material in the Martian regolith.

We conclude this editorial with the knowledge that the domain of astrobiology has spread throughout the world, enriching scientists and non-scientists in the knowledge of our universe, habitable worlds, the emergence of life, the diversity of life, the incredible survivability of life in extreme environments, and life in space. EANA will enthusiastically continue to play a central role in advocating for astrobiology in Europe and beyond.

Barbara Cavalazzi, President of EANA (2019–2022)
Frances Westall, Lena Noack, Ruth-Sophie Taubner, Tetyana Milojevic, Kai Finster, EANA Executive Councillors (2019–2022)

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