# Supplemental Material

# Email sent for the survey

Subject : Interest in one of your papers

Dear Dr. [name],

[Personal introduction]

I am working on a project to better understand attitudes toward intellectual risk and reward in Astrobiology.

To do so, I made a list of the most influential papers that can be linked to contemporary Astrobiology defined as the study of the origin, the distribution and future of life on Earth and in the Universe. In this respect, I identified your paper titled: [title] published in [Journal]in [year].

If you could please answer the following questions, I would be very grateful:

[1] Did you ever consider this research to be 'medium risk' or 'high risk', in the sense of it being 'heterodox', or simply contrary to prevailing viewpoints?

[2] Did your own results take you by surprise?

[3] To what extent was it surprising to see this paper become so influential? Did you always expect it to be 'high impact'?

Do not hesitate if you need any further information.

Thank you very much for your time.

Kind regards,

# Selection of high-impact astrobiology papers

To identify what counts as an astrobiological paper, we rely on the 2015 NASA Astrobiology Strategy report (NASA, 2015) that describes the main relevant lines of research. The 6 identified topics are as follows:

1. Identifying abiotic sources of organic compounds
2. Synthesis and function of macromolecules in the origin of life
3. Early life and increasing complexity
4. Co-evolution of life and the physical environment
5. Identifying, exploring, and characterizing environments for habitability and biosignatures
6. Constructing habitable worlds

This subdivision is only a way among others to classify astrobiology-related research, see (Horneck et al., 2015) for another proposition. Even though the delimitation of the different topics is arguable, we estimate that their overall scope faithfully represents the state of astrobiology results. The notable exclusion of SETI research doesn’t affect the reported results since it hasn’t produced significant and impactful results yet.

To make a selection of the most impactful results in astrobiology, we filtered the articles present in the Web of Science database using keywords corresponding to the six main lines of research in astrobiology as described in the "NASA astrobiology Strategy 2015" report (e.g. "astrobiology", "exobiology", "origin of life", "prebiotic chemistry", "biosignature", "habitability", "extremophile", etc). We have then selected articles reporting new results (excluding review, hypothesis, or perspective articles) that have the most citations, and we have removed articles whose results have been shown to be false as far as we know. The selected articles were published between 2001 and 2018 and we did not select more recent ones since we wish to favour results that have stood the test of time, and to reduce the chance of missing so-called “sleeping beauty” papers that start to be widely cited only several years after their publication (Ke et al., 2015).

**Table S1**. Received answers according to the related astrobiology topics



Some topics are more populated than others according to the amount of corresponding research done. For example, topic 5 is here the most populated since it includes to major research themes of astrobiology that are the issues of biosignature and habitability, applied to various bodies (e.g. exoplanets, Mars, Enceladus).

# Survey to corresponding authors of low-impact papers

To test the hypothesis that high-impact papers are more likely to come from risky projects than lower-impact papers do, we sent a similar survey to corresponding authors of low-impact astrobiological papers (FWCI <1). We contacted 38 corresponding authors of selected low-impact papers (FWCI < 1) funded by the NASA astrobiology Institute (NAI) to obtain a diverse sample of suitable projects (excluding review, opinion, or methods papers). Similarly, we selected papers with novel results, excluding review, opinion or methods papers. The NAI-funded criterion has been chosen as a way to identify a sample of low-impact astrobiology papers among the immense number of little or not cited papers. Thus, this dataset is skewed toward US-based research, but does not prevent from outlining some tendencies based on comparisons. 8 authors responded to the survey revealing a sample highly skewed towards low risk (Figure S1. A) when compared with NAI-funded high-impact papers from the previous sample (Figure S1.B). These results support the idea that high-impact results may on average derived from riskier research than low-impact results in astrobiology.

**Table S3.** Selected papers whose corresponding authors responded to the survey and results

|  |  |  |  |
| --- | --- | --- | --- |
| **Papers** | **Risk** | **FWCI** | **Results** |
| Hargitai et al., 2019 | Low | 0,17 | surprising |
| Carrasquillo et al., 2016 | Low | 0,21 | surprising |
| Hindshaw et al., 2017 | Low | 0,14 | unsurprising |
| Sobron et al., 2018 | High | 0,67 | unsurprising |
| Xiong et al., 2015 | Low | 0,14 | surprising |
| Herron et al., 2018 | Low | 0,26 | surprising |
| Lie et al., 2016 | Low | 0,39 | surprising |
| Wilpiszeski et al., 2019 | Low | 0,07 | surprising |

**Table S4**. Received answers according to the related astrobiology topics



References of the selected low-impact papers whose corresponding authors responded to the survey

Hargitai, H. I., Gulick, V. C. & Glines, N. H. Evolution of the Navua Valles region: Implications for Mars’ paleoclimatic history. *Icarus* **330**, 91–102 (2019).

Carrasquillo, A. J., Cao, C., Erwin, D. H. & Summons, R. E. Non-detection of C60 fullerene at two mass extinction horizons. *Geochimica et Cosmochimica Acta* **176**, 18–25 (2016).

Herron, M. D., Ratcliff, W. C., Boswell, J. & Rosenzweig, F. Genetics of a de novo origin of undifferentiated multicellularity. *Royal Society Open Science* **5**, 180912.

Hindshaw, R. S., Lindsay, M. R. & Boyd, E. S. Diversity and abundance of microbial eukaryotes in stream sediments from Svalbard. *Polar Biol* **40**, 1835–1843 (2017).

Lie, L., Biliya, S., Vannberg, F. & Wartell, R. M. Ligation of RNA Oligomers by the Schistosoma mansoni Hammerhead Ribozyme in Frozen Solution. *J Mol Evol* **82**, 81–92 (2016).

Sobron, P. *et al.* Dalangtan Saline Playa in a Hyperarid Region of Tibet Plateau: III. Correlated Multiscale Surface Mineralogy and Geochemistry Survey. *Astrobiology* **18**, 1277–1304 (2018).

Wilpiszeski, R. L., Zhang, Z. & House, C. H. Biogeography of thermophiles and predominance of Thermus scotoductus in domestic water heaters. *Extremophiles* **23**, 119–132 (2019).

Xiong, M. Y., Shelobolina, E. S. & Roden, E. E. Potential for Microbial Oxidation of Ferrous Iron in Basaltic Glass. *Astrobiology* **15**, 331–340 (2015).

# Figures S1, S2 and S3



**Figure S1. A. Distribution of risk assessment among high-impact NAI-funded papers**. Graph showing the proportion of high-impact NAI-funded papers the authors contacted considered to be from low, medium, or high-risk research. This sample is a subset of the sample displayed in Figure 1.A. **B. Distribution of risk assessment among low-impact NAI-funded papers**. Graph showing the proportion of low-impact NAI-funded papers the authors contacted considered to be from low, medium, or high-risk research. This sample comes from another survey than the one that led to Figure 1.



**Figure S2. Proportion of papers with surprising results per risk category**. Even though risk and paper are positively associated in the sample, the differences are not significant. The chi-square statistic is calculated as 1.524 and the p-value as 0.467.



**Figure S3. Average impact of papers with surprising and unsurprising result**. Even though papers containing surprising results are on average more impactful than the ones containing unsurprising ones in the sample, the difference is not significant. The T score is calculated as 0.371 and the p-value as 0.356.

# Bibliography

Horneck, G., Rettberg, P., Walter, N., & Gomez, F. (2015). European landscape in astrobiology, results of the AstRoMap consultation. *Acta Astronautica*, *110*, 145–154. https://doi.org/10.1016/j.actaastro.2015.01.015

Ke, Q., Ferrara, E., Radicchi, F., & Flammini, A. (2015). Defining and identifying Sleeping Beauties in science. *Proceedings of the National Academy of Sciences*, *112*(24), 7426–7431. https://doi.org/10.1073/pnas.1424329112

NASA. (2015). *NASA Astrobiology Strategy 2015* (p. 257). National Aeronautics and Space Administration.