Likely environments for studying origins of life

Nancy Merino
Post Doctoral Researcher
Lawrence Livermore National Lab

Life probably started between 4.4 to 3.8 billion years ago (Ga)

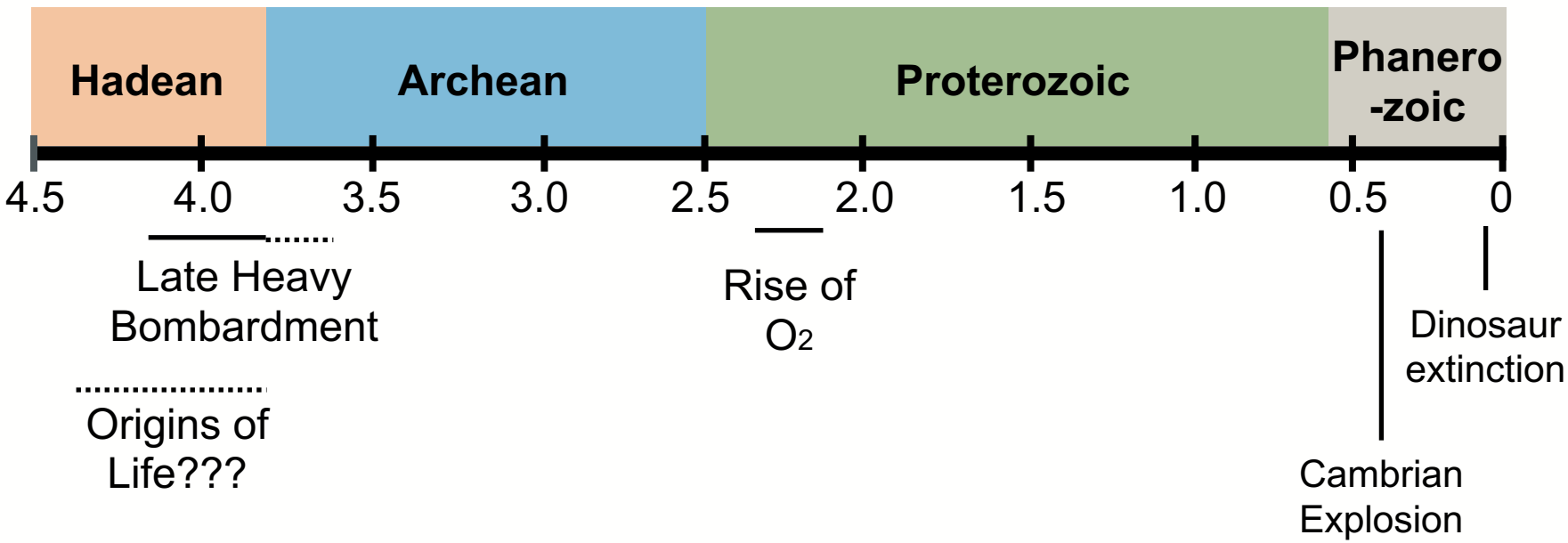


Figure modified from: Domagal-Goldman, S. D. *et al.* The Astrobiology Primer v2.0. *Astrobiology* **16**, 561–653 (2016).

Earth during the Hadean Eon was probably very inhospitable for life

Comets and Meteorite Impacts

NASA's Goddard Space Flight Center Conceptual Image Lab (artist's impression)

Earth during the Hadean Eon was probably very inhospitable for life

Comets and Meteorite Impacts

Magma Oceans formed because of:

1. Comets and meteorite impacts
2. Tidal heating (moon/Earth)
3. Core formation (plate tectonics)

Magma Oceans

NASA's Goddard Space Flight Center Conceptual Image Lab (artist's impression)

Plate tectonics helped make the early Earth environment favorable for life

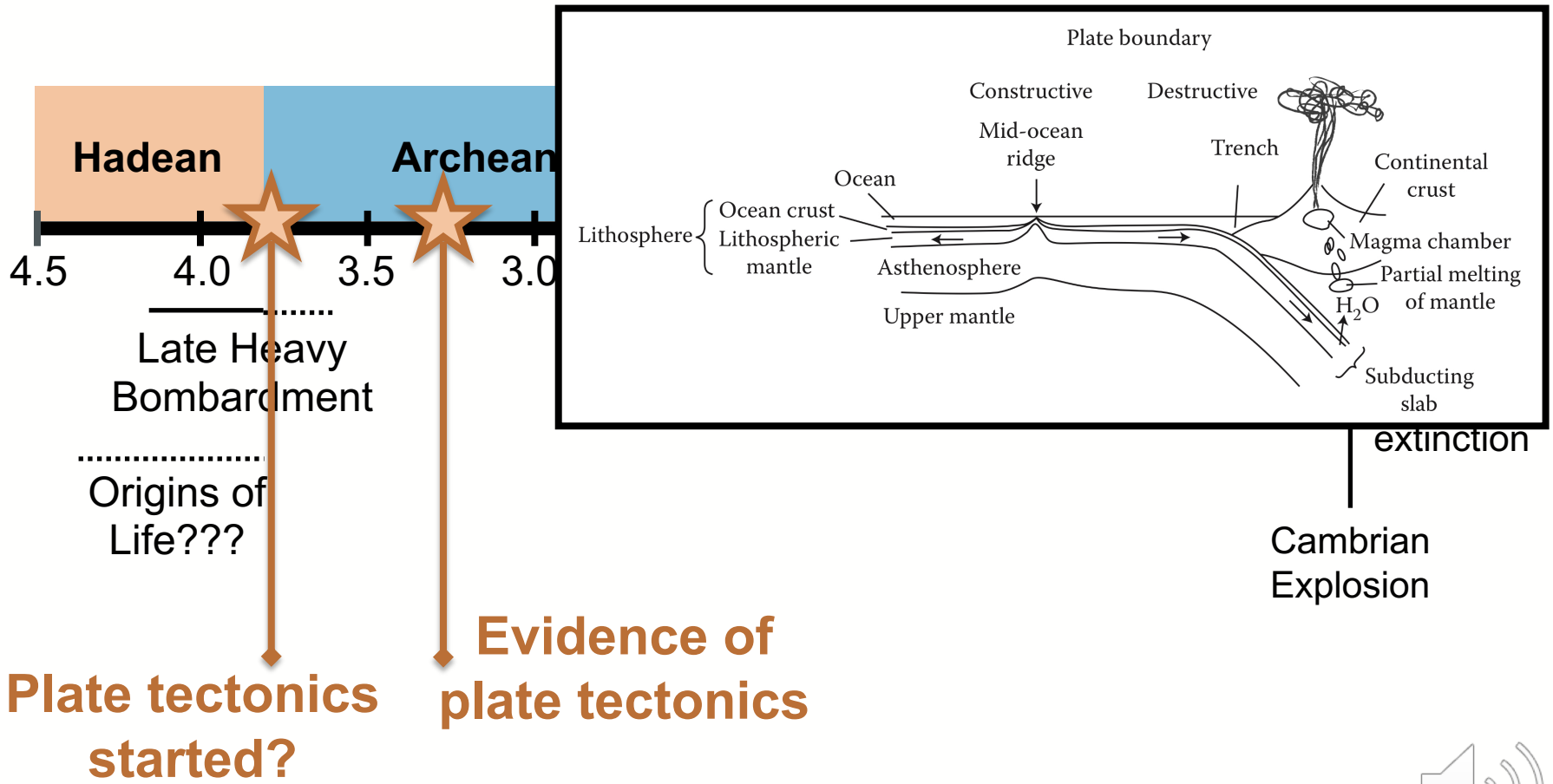


Figure modified from: Domagal-Goldman, S. D. *et al.* The Astrobiology Primer v2.0. *Astrobiology* **16**, 561–653 (2016).
Figure of plate tectonics: Longstaff, Alan. Astrobiology: An Introduction. CRC Press, Taylor & Francis Group, 2015.

Global oceans probably covered the surface of the Earth by the Archean Eon

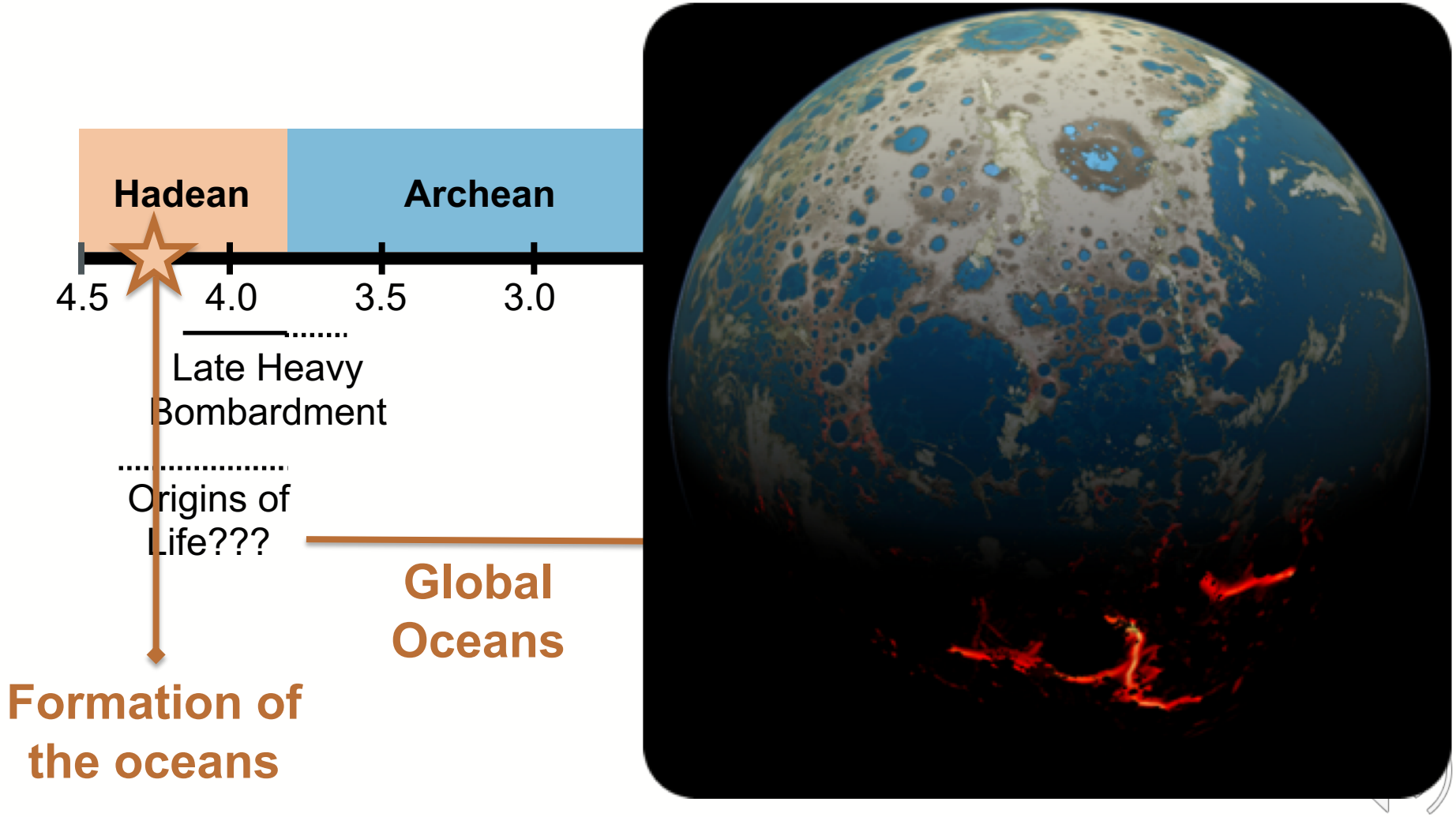
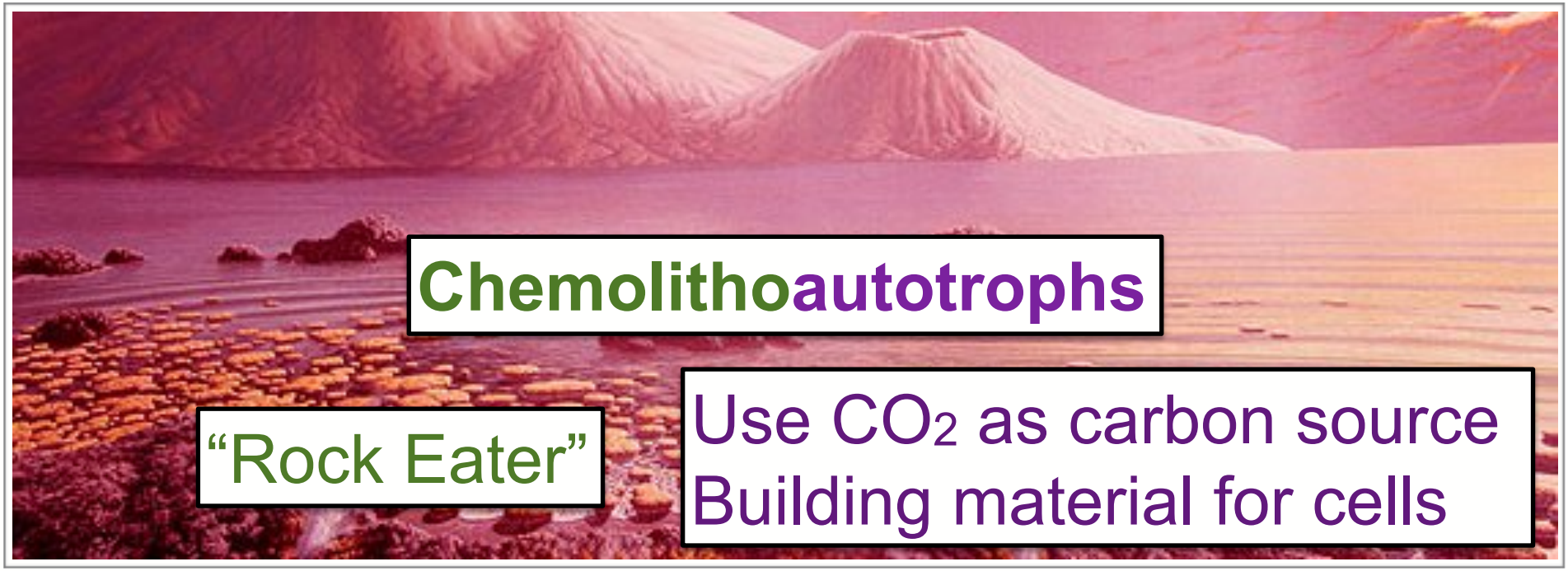


Figure modified from: Domagal-Goldman, S. D. *et al.* The Astrobiology Primer v2.0. *Astrobiology* **16**, 561–653 (2016).

Life took hold on Earth during the Archean Eon

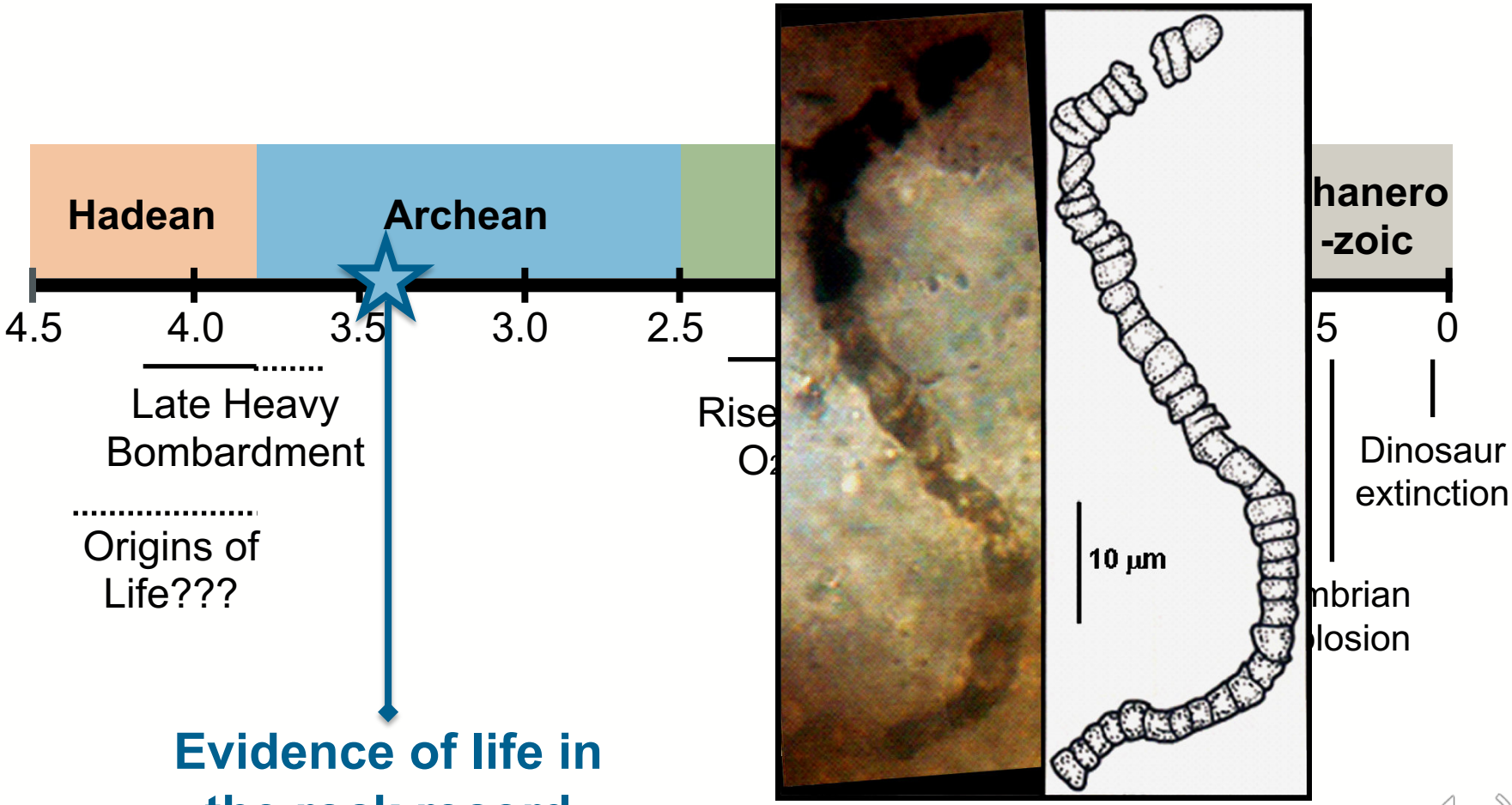
Peter Sawyer / Smithsonian Institution (artist's impression)

Life took hold on Earth during the Archean Eon



Peter Sawyer / Smithsonian Institution (artist’s impression)

The first likely signs of life in the rock record dates back to 3.5 to 3.3 Ga



Evidence of life in the rock record

Figure modified from: Domagal-Goldman, S. D. *et al.* The Astrobiology Primer v2.0. *Astrobiology* **16**, 561–653 (2016).
Figure: Schopf, J. William, et al. SIMS Analyses of the Oldest Known Assemblage of Microfossils Document Their Taxon-Correlated Carbon Isotope Compositions. *PNAS.* **115**, 53-58 (2018).

How can we think about early life?

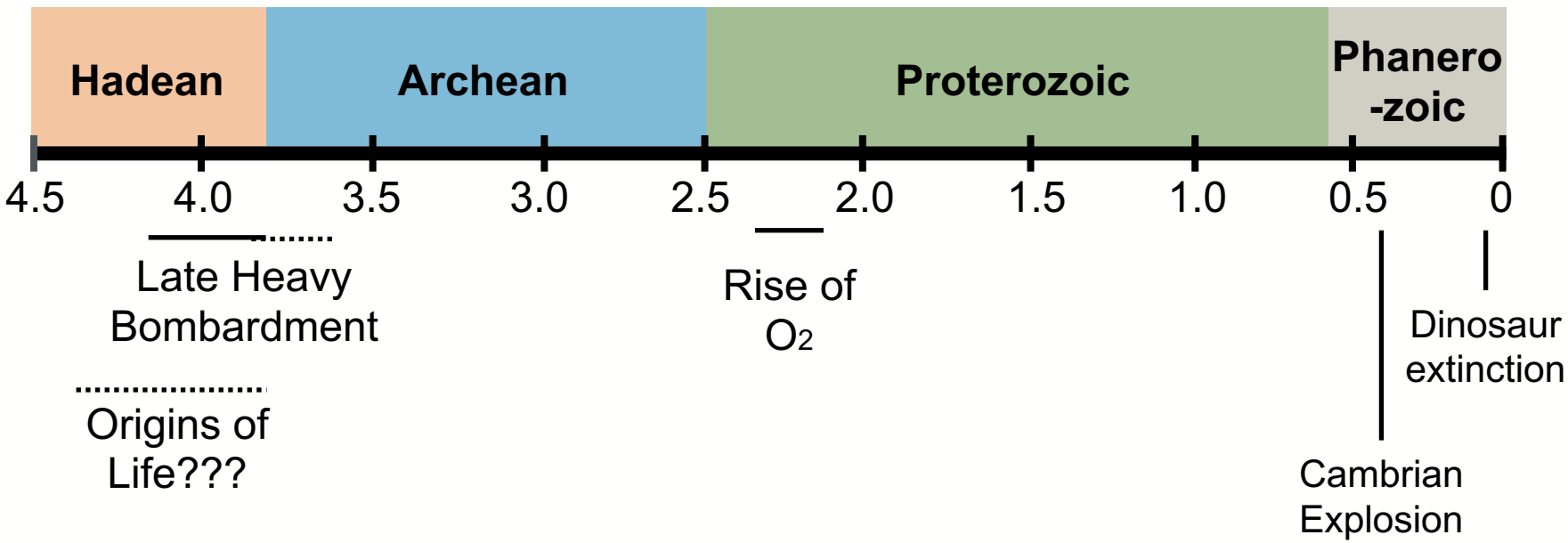


Figure modified from: Domagal-Goldman, S. D. *et al.* The Astrobiology Primer v2.0. *Astrobiology* **16**, 561–653 (2016).

How can we think about early life? And life on other planetary bodies??

Look at modern-day analogues!!

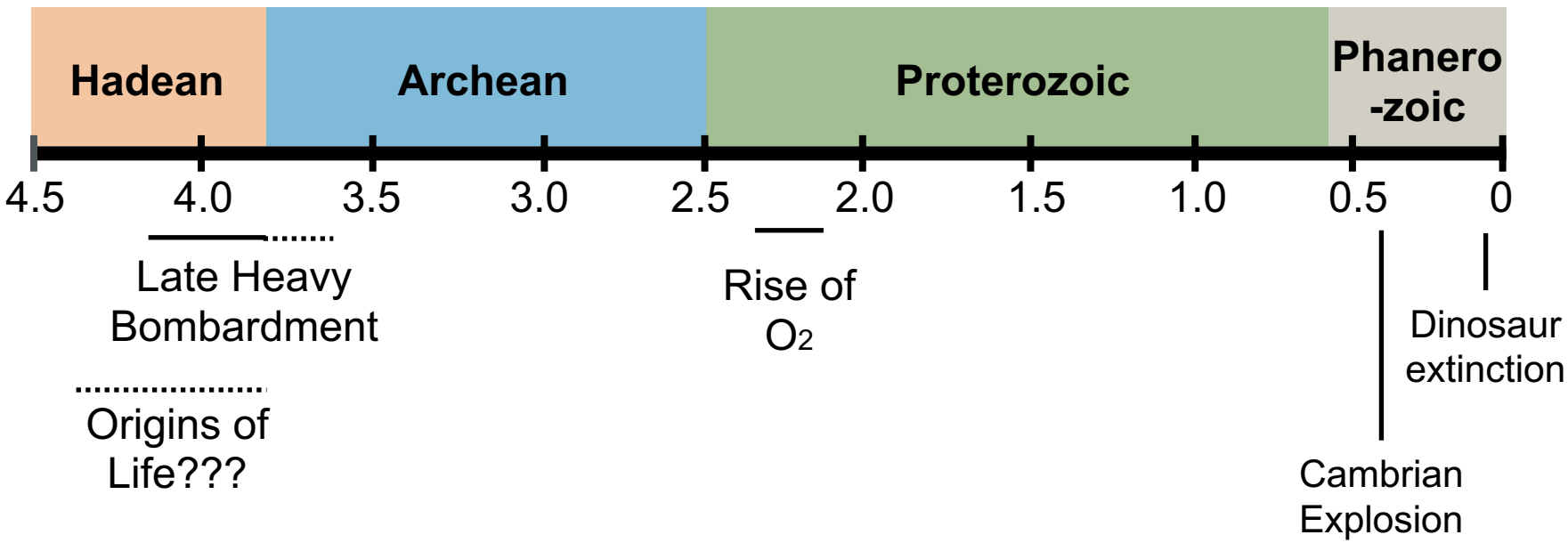
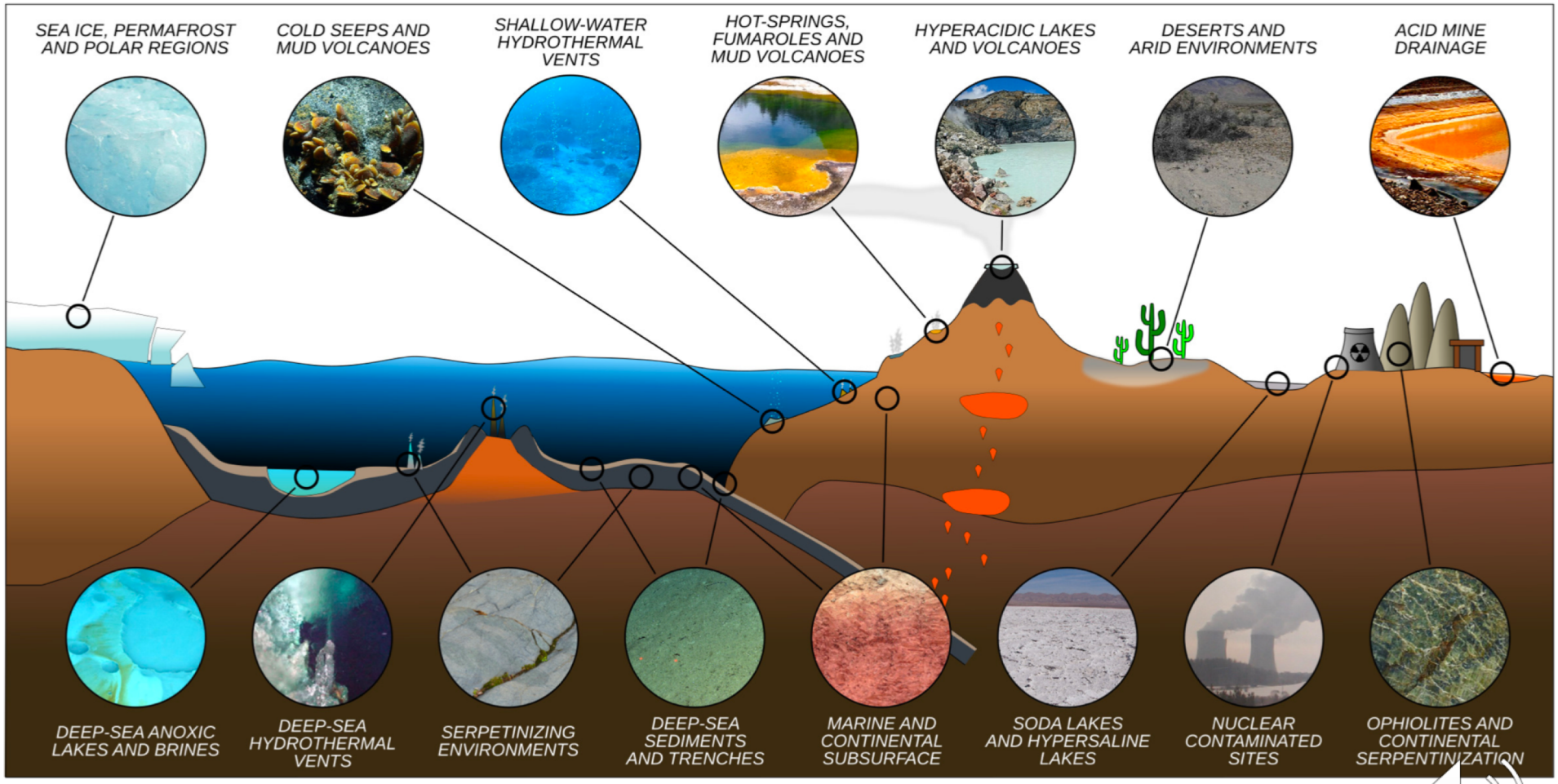


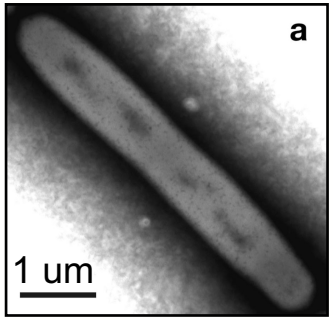
Figure modified from: Domagal-Goldman, S. D. *et al.* The Astrobiology Primer v2.0. *Astrobiology* **16**, 561–653 (2016).

There are many modern-day analogues for Early Earth and other planetary bodies

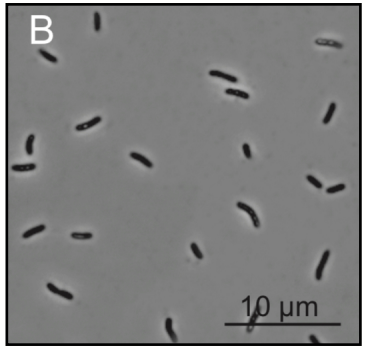


Merino, N. et al. Living at the Extremes: Extremophiles and the Limits of Life in a Planetary Context. Frontiers in Microbiology 10, 780 (2019).

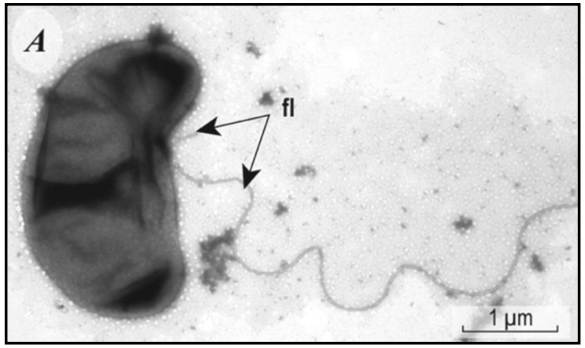
Many microorganisms can survive under extreme conditions ("extremophiles")



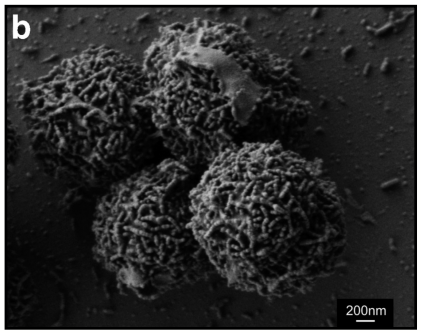
Hyperthermophile (T 122ºC)
Piezophile (40 MPa)
Methanopyrus kandleri strain 116
Takai et al. 2008



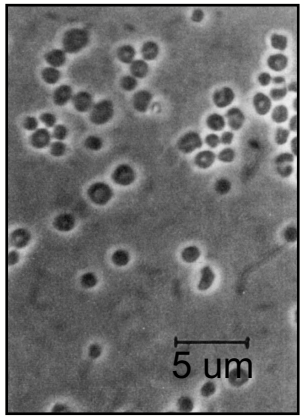
Alkaliphile (pH12.5)
Serpentinomonas sp. B1
Suzuki et al. 2014



Haloalkaliphile (35% salinity)
Halarsenatibacter silvermanii strain SLAS-1
Blum et al. 2009



Halopsychrophile (T -15ºC)
Planococcus halocryophilus Or1
Mykytczuk et al. 2013



Hyperacidophile (pH -0.06)
Picrophilus oshimae
Schleper et al. 1996

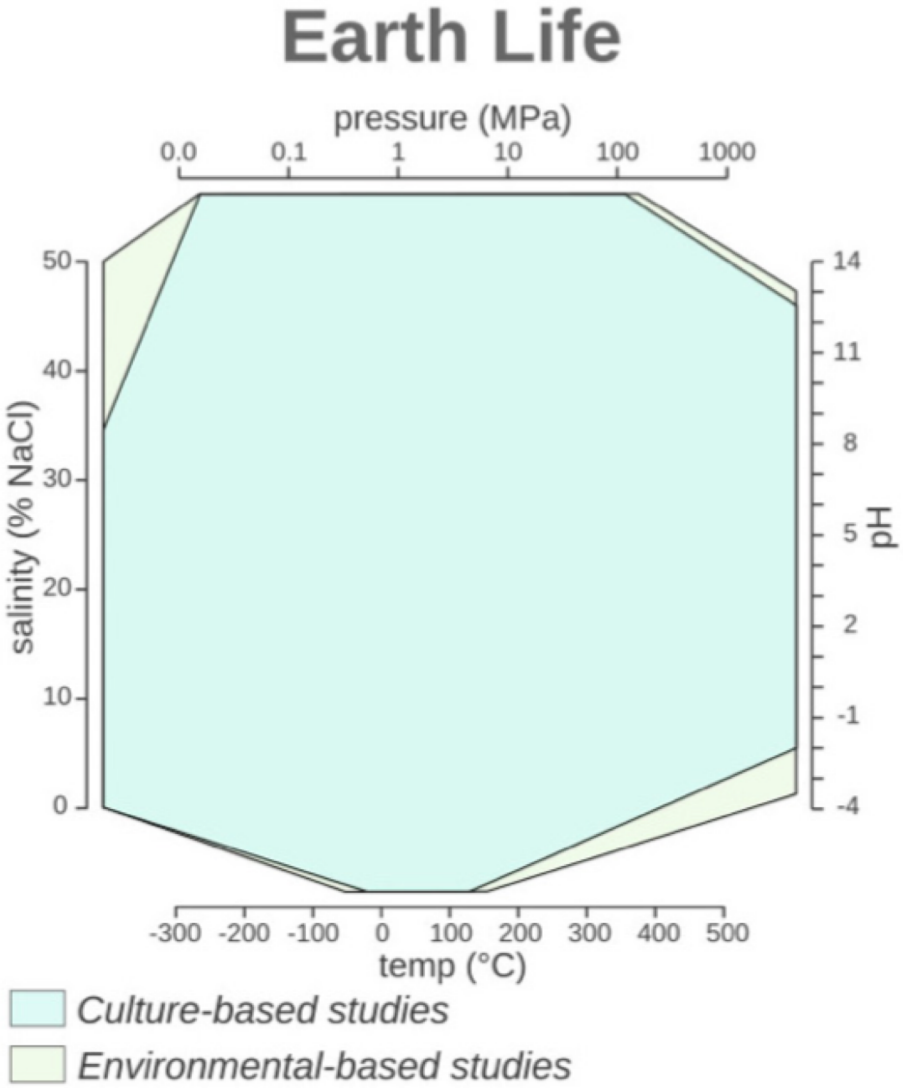
Extremes include:

- Temperature
- pH
- Salinity
- Pressure
- Desiccation
- Radiation-tolerant

Multiple extremes = "Polyextremophiles"

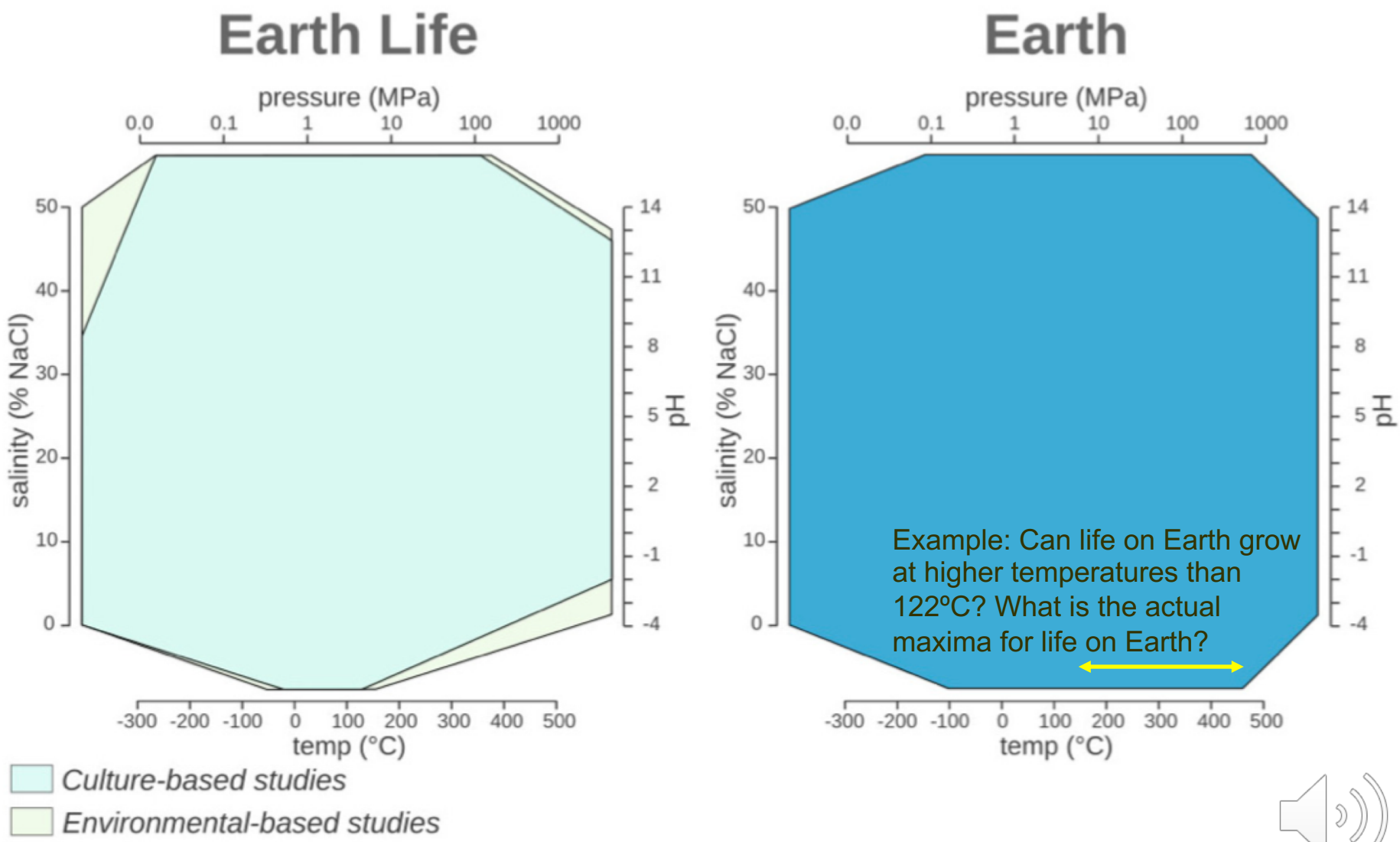
Merino, N. et al. Living at the Extremes: Extremophiles and the Limits of Life in a Planetary Context. Frontiers in Microbiology 10, 780 (2019).

Life on Earth could potentially survive under even more extreme conditions



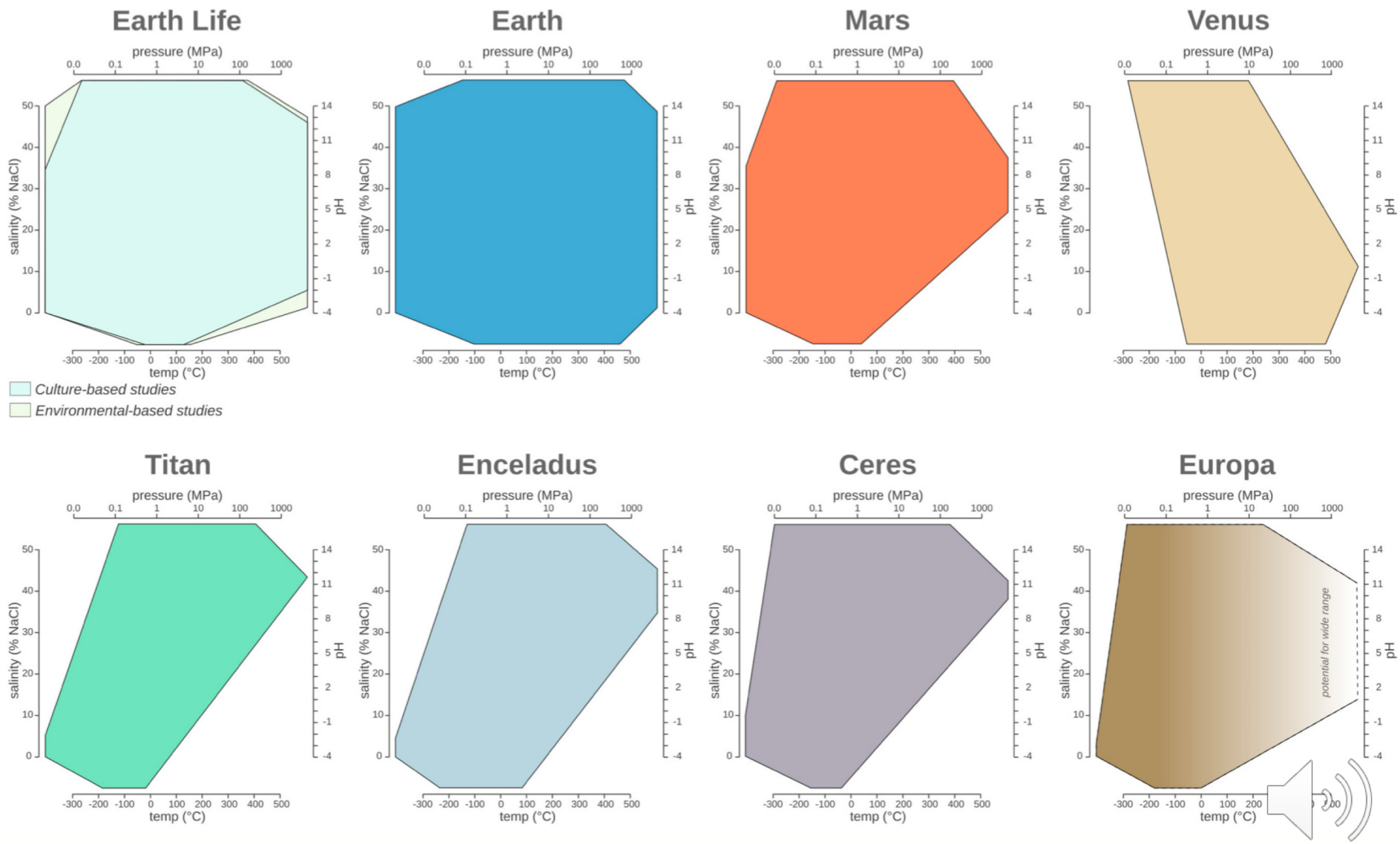
Merino, N. et al. Living at the Extremes: Extremophiles and the Limits of Life in a Planetary Context. Frontiers in Microbiology 10, 780 (2019).

Life on Earth could potentially survive under even more extreme conditions



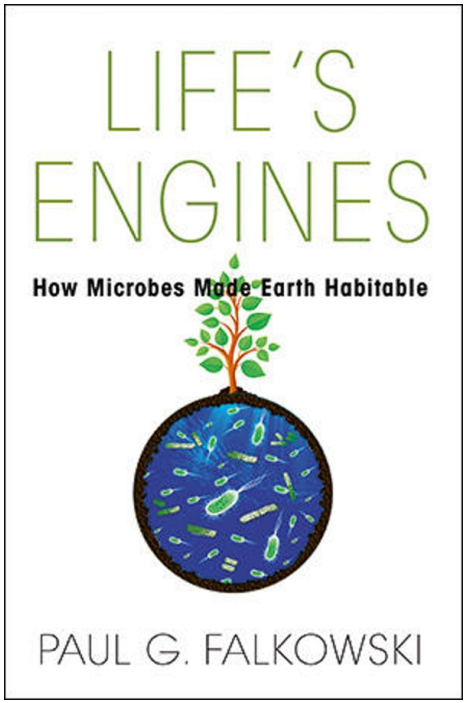
Merino, N. et al. Living at the Extremes: Extremophiles and the Limits of Life in a Planetary Context. Frontiers in Microbiology 10, 780 (2019).

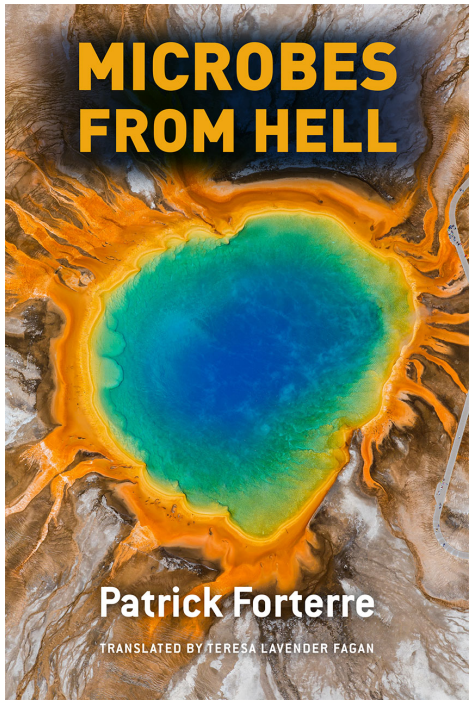
What about other planetary bodies?

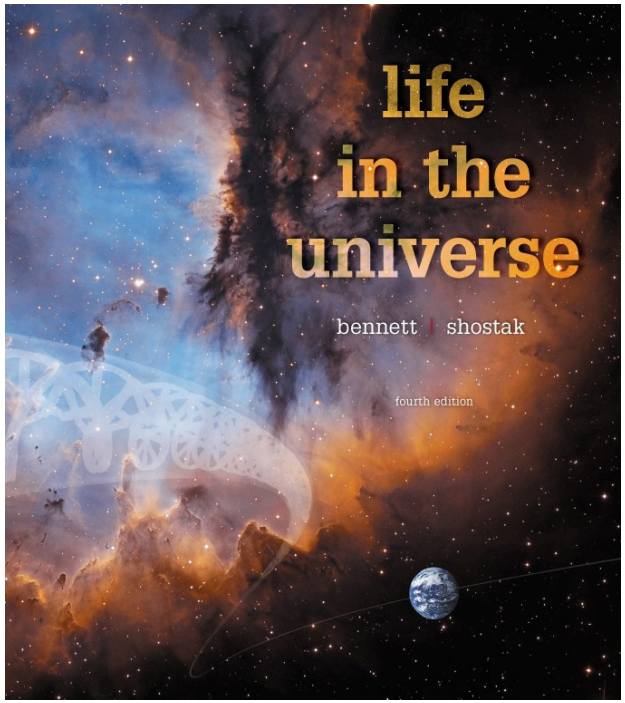


Merino, N. et al. Living at the Extremes: Extremophiles and the Limits of Life in a Planetary Context. Frontiers in Microbiology 10, 780 (2019).

Suggested Reading







References

1. Blum, J. S., Han, S., Lanoil, B., Saltikov, C., Witte, B., Tabita, F. R., et al. (2009). Ecophysiology of “Halarsenatibacter silvermanii” Strain SLAS-1T, gen. nov., sp. nov., a Facultative Chemoautotrophic Arsenate Respirer from Salt-Saturated Searles Lake, California. Appl. Environ. Microbiol. 75, 1950–1960. doi:10.1128/AEM.02614-08.
2. Branscomb, E., and Russell, M. J. (2013). Turnstiles and bifurcators: the disequilibrium converting engines that put metabolism on the road. Biochim. Biophys. Acta 1827, 62–78. doi:10.1016/j.bbabio.2012.10.003.
3. Cottin, H., Kotler, J. M., Bartik, K., Cleaves, H. J., Cockell, C. S., de Vera, J.-P. P., et al. (2017). Astrobiology and the Possibility of Life on Earth and Elsewhere…. Space Sci Rev 209, 1–42. doi:10.1007/s11214-015-0196-1.
4. Domagal-Goldman, S. D., Wright, K. E., Adamala, K., Arina de la Rubia, L., Bond, J., Dartnell, L. R., et al. (2016). The Astrobiology Primer v2.0. Astrobiology 16, 561–653. doi:10.1089/ast.2015.1460.
5. Longstaff, A. (2015). Astrobiology: an introduction. Boca Raton: CRC Press, Taylor & Francis Group.
6. Martins, Z., Cottin, H., Kotler, J. M., Carrasco, N., Cockell, C. S., de la Torre Noetzel, R., et al. (2017). Earth as a Tool for Astrobiology—A European Perspective. Space Sci Rev 209, 43–81. doi:10.1007/s11214-017-0369-1.
7. Merino, N., Aronson, H. S., Bojanova, D. P., Feyhl-Buska, J., Wong, M. L., Zhang, S., et al. (2019). Living at the Extremes: Extremophiles and the Limits of Life in a Planetary Context. Front. Microbiol. 10. doi:10.3389/fmicb.2019.00780.
8. Mykytczuk, N. C. S., Foote, S. J., Omelon, C. R., Southam, G., Greer, C. W., and Whyte, L. G. (2013). Bacterial growth at -15 °C; molecular insights from the permafrost bacterium Planococcus halocryophilus Or1. ISME J 7, 1211–1226. doi:10.1038/ismej.2013.8.
9. Schleper, C., Puhler, G., Klenk, H.-P., and Zillig, W. (1996). Picrophilus oshimae and Picrophilus torridus fam. nov., gen. nov., sp. nov., Two Species of Hyperacidophilic, Thermophilic, Heterotrophic, Aerobic Archaea. International Journal of Systematic Bacteriology 46, 814–816. doi:10.1099/00207713-46-3-814.
10. Schopf, J. W., Kitajima, K., Spicuzza, M. J., Kudryavtsev, A. B., and Valley, J. W. (2018). SIMS analyses of the oldest known assemblage of microfossils document their taxon-correlated carbon isotope compositions. PNAS 115, 53–58. doi:10.1073/pnas.1718063115.
11. Suzuki, S., Kuenen, J. G., Schipper, K., van der Velde, S., Ishii, S., Wu, A., et al. (2014). Physiological and genomic features of highly alkaliphilic hydrogen-utilizing Betaproteobacteria from a continental serpentinizing site. Nat Commun 5. doi:10.1038/ncomms4900.
12. Takai, K., Nakamura, K., Toki, T., Tsunogai, U., Miyazaki, M., Miyazaki, J., et al. (2008). Cell proliferation at 122°C and isotopically heavy CH4 production by a hyperthermophilic methanogen under high-pressure cultivation. PNAS 105, 10949–10954. doi:10.1073/pnas.0712334105.