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The habitability of the Earth over geologic time and the search for life elsewhere

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The question of whether life exists beyond Earth is ancient, but recent technological and scientific advances mean that such life could be discovered in the next decade or two. For example, life might be identified from the spectrum of an exoplanet's atmosphere or in the subsurface of Mars. Consideration of life elsewhere forces us to think about what makes a planet habitable. In particular, thousands of exoplanets -- planets around other stars – are now known, and it is only a matter of time before Earth-sized, rocky bodies in the liquid water habitable zone of nearby stars present us with real cases of possible habitability and possible life.

When we compare the very different climates on Venus, Earth and Mars, it is clear that an understanding of geochemical volatiles and atmospheric evolution is critical for determining whether a planet is potentially habitable. Much work remains to be done to improve our grasp of the evolution of the Earth, which serves as our point of reference for comparing other planets. Where did Earth's atmosphere come from, and how did the mixture of gases in the atmosphere change over billions of years since Earth's origin? New evidence and numerical simulations suggest that negative feedbacks involving a carbon sink in seafloor and continental rock weathering have moderated levels of CO_2 on geological timescales and stabilized Earth's climate system, despite an increase of almost ten percent every billion years in solar luminosity. Ocean pH, on geological timescales, is linked to this system of geologic feedbacks on carbon, and affects marine biology. Geochemical evidence also shows that Earth's biosphere greatly altered the Earth's atmosphere. Various changes in atmospheric gases are reflected in various aspects of the geologic record: isotope systems through time, the bulk composition of rocks derived from marine and non-marine sediments, and occasionally in physical aspects of rocks.

I will review recent advances in our understanding of the co-evolution of life and environment on Earth from the Archean to the modern day. I will also consider how such an understanding helps in the search for biosignatures beyond Earth, i.e., substances, groups of substances, or phenomena that indicate the presence of life.