

Assessing the habitability of Jupiter's moon Europa

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Europa, one of Jupiter's Galilean moons, has become a compelling candidate in the search for extraterrestrial habitability within our solar system. Habitability is commonly defined as the capacity of an environment to support life, requiring at minimum the presence of liquid water, a sustained energy source, and essential chemical building blocks. Evidence suggests there is a global subsurface ocean of liquid water beneath Europa's icy surface, maintained by tidal heating generated through gravitational interactions with Jupiter and neighboring moons. These conditions make Europa a prime target for astrobiological investigation.

The surface of Europa is characterized by a thick ice shell, which is estimated to be several kilometers deep, and both shields and isolates the underlying ocean. Observations from spacecraft missions, particularly NASA's Galileo mission, have revealed a young and dynamic surface marked by fractures, ridges, and chaotic terrains. These features indicate active geological processes and suggest that material exchange may occur between the surface and the subsurface ocean. Such exchange is crucial for habitability, as it could allow oxidants produced by radiation at the surface to mix with reductants from the ocean floor, creating chemical energy gradients suitable for life.

Europa's ocean is believed to be in direct contact with a rocky mantle, raising the possibility of hydrothermal activity at the seafloor. On Earth, hydrothermal vents host diverse ecosystems that rely on chemosynthesis rather than sunlight, demonstrating that life can thrive in environments previously considered extreme. If similar hydrothermal systems exist on Europa, they could provide both energy and essential nutrients, such as dissolved minerals and organic compounds, supporting microbial life.

However, several uncertainties remain regarding Europa's habitability. The thickness of the ice shell, the salinity and composition of the ocean, and the availability of key bioessential elements such as carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur are not yet fully constrained. Additionally, the intensity of radiation at Europa's surface poses challenges for potential life near or above the ice shell, although the subsurface ocean would be largely protected. Future missions, such as NASA's Europa Clipper and ESA's JUICE, aim to address these uncertainties by providing key data of Europa's ice shell, ocean properties, and surface chemistry.