BIOLUMINESCENCE: A POTENTIALLY CONVERGENT SIGNATURE OF LIFE IN FUTURE EXPLORATION OF EUROPA'S SUBSURFACE OCEAN. C. L. Flores Martinez[1], [1]University of Heidelberg, Centre for Organismal Studies, Im Neuenheimer Feld 234, 69120 Heidelberg, Baden-Wurttemberg, Germany, e-mail: c.flores@stud.uni-heidelberg.de

Introduction: The long-term exploration strategy of Europa and its potential global subsurface ocean envisions the future *in situ* probing for life of the local aquatic environment with an integrated approach that uses a melting probe carrying a second-stage autonomous underwater vehicle (AUV). However, accurately predicting the exact nature of putative biological activity on Europa is extremely difficult. This is due to an unsolved and fundamental problem in evolutionary biology, namely the contingency vs. convergence debate. It is far from certain if stable trajectories exist, leading from mechanistically identical origins of life towards higher forms of biological organization, which are independently and repeatedly, and thus in a convergent manner, traced by the process of evolution within planetary biospheres apart from Earth. Therefore it appears to be useful to address the possibility of convergent evolution in two unrelated evolutionary systems that emerged and subsequently evolved and developed independently. [1,2]

Convergent Evolution and Biosignatures: Firstly, basic theoretical considerations are undertaken pertaining to the possibility of convergent biological processes occurring at an interplanetary and cosmic scale in a Universe that seems to exhibit a natural propensity towards biogenesis. Next, the concept of *convergent biosignatures* will be introduced [1]. This term refers to independently evolved and potentially detectable organismic features of putative extraterrestrial life forms, and, more specifically, adaptations of such organisms that could be predicted on the basis of their repeated emergence on Earth. Ideally, such traits should be detectable without a detailed knowledge of the underlying molecular physiology.

The Emergence of Bioluminescence in the Ocean of Europa: Secondly, one obvious example of such a hypothesized convergent signature of life, bioluminescence, will be discussed within the context of Europa's oceanic environment. On Earth the repeated emergence of bioluminescence systems, mainly in marine organisms, occurred more than forty times in many branches of the tree of life, ranging from bacteria to complex animals such as fish and squid [3,4]. These systems employ a variety of underlying chemistries and evolved ca. 400 – 800 Mya ago as a mechanism for oxygen defense. At the core of every kind of bioluminescence lies a strictly oxygen-dependent biochemical reaction between a substrate (luciferin) and a taxon-specific enzyme (luciferase). One of the products of such a reaction is biologically produced, cold light. For the emergence of bioluminescence within the ocean of Europa a habitable environment is assumed in which: life originates rapidly from hydrogeological serpentinizing systems on the seafloor [5], evolves into chemoautotrophic forms, which, then, radiate into free-floating colonies, some of which might gain multicellular organization, able to harness energy gradients via ATP-like transduction mechanisms not commonly used by terrestrial life [6,7]. At some point during Europa's planetary history these pioneering organisms might encounter rising oxygen concentrations due to surface-ocean exchange of oxidants [8]. Various chemical systems could then be transformed into pathways for consuming ambient oxygen in bioluminescence-type reactions. Multicellular organisms, if present, could potentially even possess primitive visual systems deriving from infrared detecting sensory adaptations that emerged during hydrothermal system-centered evolution and development of complex life. This would be the major requirement for the co-opting of bioluminescence into a functional communication and signaling device.

Detection of Biological Light in Future Exploration: Lastly, it is described how bioluminescence, an unambiguous signature of life in an otherwise aphotic environment, either found in micro- or multicellular complex organisms, could be imaginably detected by an advanced AUV equipped with a space-mission adapted bathy-photometer or via biomimicry using the optical luring technique [9,10]. Prototype testing and calibration of this kind of instrumentation could conceivably be conducted at terrestrial analogues of Europa's subsurface ocean, for instance the sea below Antarctica or subglacial lakes.

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