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Panspermia, Past and Present: Astrophysical and Biophysical Conditions for the Dissemination of Life in Space

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Abstract Astronomically, there are viable mechanisms for distributing organic material throughout the Milky Way. Biologically, the destructive effects of ultraviolet light and cosmic rays means that the majority of organisms arrive broken and dead on a new world. The likelihood of conventional forms of panspermia must therefore be considered low. However, the *information* content of damaged biological molecules might serve to seed new life (necropanspermia).

Keywords Radiation pressure · Cosmic rays · Micro-organisms · Viruses · Information

1 Introduction

Panspermia is underlain by the idea that the vast number of stars in the Milky Way is somehow matched by the fecundity of life. Astronomical conditions are such that it appears feasible to transport organic material from one star system to another; but those same conditions mean that biological damage is severe (notably due to ultraviolet light and cosmic rays), so the majority of organisms arrive on a new world in an inactivated or dead state. The majority opinion is that while organisms may be ejected from an Earth-like planet by the collision of an asteroid or comet, the DNA and RNA is so degraded in space that the probability of seeding life in the Galaxy is low. Despite this, interest in the origin of life is high, and mechanisms continue to be investigated that might lead to a viable version of panspermia.

Lithopanspermia, wherein life is distributed through space on rocks such as meteorites, was suggested by Lord Kelvin in an address to the British Society for the Advancement of Science in 1871. Radiopanspermia, which involves the movement of organisms by the radiation pressure of the Sun and other stars, was discussed by Arrhenius in his book *Worlds*

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in the Making of 1908. Subsequent to these two ground-breaking suggestions, the possible role of cosmic rays was discussed, since the low-energy particles which form the solar wind and the fluxes of ionizing radiation from other stars join with higher-energy particles from astrophysical sources to inactivate (or kill) micro-organisms in space. Directed panspermia was proposed by Crick and Orgel (1973) in an attempt to circumvent both the transport and inactivation problems, and envisages a technologically-advanced alien civilization which purposefully sent spaceships laden with micro-organisms to seed life throughout the early Milky Way. Recently, however, it has been argued that the same end may be achieved by natural mechanisms under favourable circumstances (Wallis and Wickramasinghe 2004). Microbial life can be protected from ultraviolet photons and cosmic-ray particles if it is buried in rocky objects of 1 mm–1 m size, and after traversing the comet-laden outer parts of a planetary system and being slowed by a protostellar disk or giant molecular cloud (Napier and Staniucha 1982), the surviving organisms may be deposited on a remote planet, which if hospitable would provide a new home for life.

Variations on these versions of panspermia are numerous (Hart 1982; Cosmovici et al. 1997; Hoyle and Wickramasinghe 2000; Burchell 2004; Sullivan and Baross 2007). Here, what may be termed the standard model is assumed. In this, micro-organisms in rocky material are ejected into space following an impact by an asteroid or comet on an Earth-like planet, the material being ejected from the solar system, to travel through interstellar space before entering another planetary system, where the organisms are deposited on a new world. Detailed calculations on this model have been done by several groups (Secker et al. 1994; Clark et al. 1999; Mileikowsky et al. 2000; Melosh 2003; Valtonen et al. 2009). The consensus view is that radiation pressure is the dominant mechanism for accelerating organism-laden material of grain size out of the first planetary system and decelerating it into the second system; and that ultraviolet light is the dominant mechanism for inactivating organisms in space, which even if they are partially shielded by rocky material happens on a timescale of 10^6 yr (see below). However, there are significant differences of opinion about the contending influences of electromagnetic radiation and cosmic rays. In Sects. 2 and 3 below, the astrophysical and biophysical conditions around panspermia will be examined anew. A simplified, bolometric calculation will be done which complements an earlier spectral one (Secker et al. 1994). This will confirm that radiation pressure is the dominant transport mechanism, and that most micro-organisms are indeed killed by ultraviolet light. However, it will be noted that because of their sizes and nature, a possible niche for panspermia might be filled by viruses or fragments of them. In fact, a new aspect of panspermia is revealed if we concentrate not on the question of alive-versus-dead (which is difficult to evaluate), but on the question of genetic *information* (which can be quantified; Wesson et al. 1997). Since viruses are commonly regarded as intermediate between 'living' and 'dead', and are not normally considered as panspermia agents, a short account of their relevant properties is given in the Appendix. Section 4 is a conclusion.

It will become clear that considerable uncertainties remain about panspermia, even though significant advances have been made recently. Of these, a major one is the realization that a few meteorites found on Earth must have originated on the Moon and on the planet Mars. This confirms the feasibility of the first stage of panspermia, as argued by Melosh (1988, 2003), though he and other workers have voiced skepticism about the later stages of the process. Another discovery is that some forms of life—the extremophiles—exist on the Earth in environments that are very inhospitable compared to what was previously considered normal. Some of the uncertainty about panspermia is related to another question that is notoriously troublesome, namely how to define 'life' (Cleland and Chyba 2007; Shapiro 2007; Abbot et al. 2008). This topic is beyond the scope of the present account.