〈教育セミナー〉

生物の進化と環境適応
—光は生命なり—

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Review: Sunlight and Its Children from Cyanobacteria to Humans

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Abstract

Animals cannot live without plants. Plants cannot live without sunlight. The sun was worshipped as a god by ancient people but is not so by modern civilized people. Among living things, cyanobacteria are the best adapted to the global environments as they require water, air and sunlight only. The marine cyanobacterium, *Trichodesmium*, inhabits the tropical and subtropical oceans of Pacific, Indian and Atlantic oceans; they fix nitrogen gas under fully aerobic conditions while photosynthetically evolving oxygen.[1] *Trichodesmium* must possess highly developed defense mechanisms against poisonous environmental toxins, oxygen and solar UV (ultraviolet). The photoreactivation (PR) is the most efficient repair of UV-induced lesions in DNA. In embryos of *D. melanogaster*, UV induced lethal damage can be nearly 100% repaired by posttreatment with visible light.[7] Photolyase responsible for PR activity is present from bacteria to marsupial mammals but not in eutherian mammals.[5] PR may be no longer needed by eutherians as a result of the uterus' protection until birth of the embryo against solar UV. NER (nucleotide excision repair) is another mechanism to eliminate UV damage in DNA. NER is in principle similar from bacteria to mammals.[5] By contrast to PR, NER is present not only in humans but also in nocturnal mice, indicating the possibility that mammalian NER deals with DNA lesions caused not only by UV but also by oxygen. Evidence supporting this possibility is as follows. XPA (xeroderma pigmentosum of complementation group A) is caused by total NER deficiency and CS (Cockayne syndrome) by deficiency in TCR (transcription-coupled repair, the specialized form of NER). XPA individuals are extremely sensitive to UV, suffer from high incidences of skin cancers, considerable increases in cancers of internal organs, and most also suffer from neurological symptoms.[5] CS individuals are only moderately sensitive to UV, and not susceptible to skin cancer, but suffer from severe developmental and neurological abnormalities, showing cachectic dwarfism and teenage death.[5] From recent reviews,[6),9)] the following scenario emerges to explain XPA and CS phenotypes. RNA Pol II molecules stalled at oxidative lesions on the template strands of active genes never resume transcription, because mutant CS molecules are unable to recruit NER repairsomes. RNA Pol II molecules are tethered to lesions in a frozen state in that they become resistant to proteolytic degradation due to their defective ubiquitination resulting from binding to mutant CS molecules. Thus, the number of frozen RNA Pol II molecules tethered to oxidative lesions increases with increase in age after birth for the brain and other organs where the cell renewal function has stopped operation. Resulting age-dependent progressive suppression of transcription activities in the brain and other non-cell-renewing organs will lead to a systemic downregulation of the whole body metabolism, perhaps partly explaining the severe symptoms of CS patients and also resistance to carcinogenesis that depends on active metabolism. Similar but rather mild symptoms in XPA patients may result from the circumstance that RNA Pol II molecules are tethered to oxidative lesions in the same way as in CS patients but they are not frozen as they are associated with normal CS molecules. Lesson from studies of XPA and CS patients shows that mammalian NER has developed to an incredibly exquisite level to repair various types of DNA lesions induced by environmental toxins which mammalian ancestors had encountered during the evolutionary pathway.

Key words: evolution, cyanobacteria, ultraviolet damage, nucleotide excision repair, photoreactivation, xeroderma pigmentosum, Cockayne syndrome, oxidative lesions.