Sex, Death and Kefir

The certainty of death was absent at the origin of life. Unlike humans and other mammals, many organisms do not age and die. The process of programmed, inevitable death evolved only after our symbiotic microbial ancestors, some two billion years ago, became sexual individuals.

Any organism can die because of circumstances beyond its control: the ambience grows too hot, a predator attacks, poison gas permeates. But programmed death happens independently of environmental action: cornstalks topple at the end of the season, or a healthy elephant succumbs at the end of a century. Monthly, in menstruating women, the dead cells of the uterine lining flow through the vagina. Each autumn in the deciduous trees and shrubs of the North Temperate Zone, rows of cells at the base of the leaf stem die.

Unlike animals and plants that grow from embryos and die on schedule, all bacteria and most other microorganisms remain eternally young. These other organisms are protoctists and fungi. Protoctists constitute a diverse group that includes our animal ancestors, as well as seaweeds, ciliates, slime molds, foraminifera, diatoms and many others. Like the fungi (yeasts, molds and mushrooms), protoctists are symbiotic aggregates of nucleated cells that reproduce by cell division. Protoctist and fungal individuals can grow and reproduce without any sexual partners.

But in some protoctists—those that became the ancestors of the fungi, plants and animals—our kind of sex, which involves mating and cell fusion by fertilization, first appeared. I propose that it did so as an accidental consequence of a desperate strategy for survival. Sex began when unfavorable seasonal changes in the environment caused our protoctist predecessors to engage in attempts at cannibalism that were only partially successful.

The result was a monster bearing the cells and genes of at least two individuals (as does the fertilized egg today). The return of more favorable environmental conditions selected for survival those monsters able to regain their simpler, normal identity. To do so, each had to slough off half or more of the "extra" cell remains. Death and the genes that caused death evolved. "Death genes" have now been isolated and their operation studied. Lawrence M. Schwartz, here at the University of Massachusetts, for example, can predict the demise of cells in a laboratory culture to within a few hours when he introduces DNA containing death genes.

Those microbial ancestors that fused survived, whereas those that evaded sexual liaisons died. Cell fusion that guaranteed survival triggered development of simpler, normal individuals again. Those very few individuals that indulged each winter or dry season in body fusion and its relief by death of extra genes and cells survived to become our sexual ancestors. Cannibalistic fusion and its thwarting by programmed death became inextricably linked to seasonal survival and to individuality. Embryo development required sex cell fusion, cell movement, cell interaction and programmed cell death. It still does.

Surprisingly, kefir, a nutritious drink popular in the Caucasus Mountains of southern Russia and Georgia, illustrates how symbiogenesis—the appearance of new species by symbiosis—works and how, in evolution, symbiosis preceded sex. Kefir refers both to the effervescent dairy drink and to the individual curds that ferment milk to make the drink. These curds, like our eventually sexy protoctist ancestors, evolved symbiogenetically.

Legend says the prophet Muhammad gave the original kefir curds to the Orthodox Christian peoples near Mount Elbrus with strict orders never to give them away. Nevertheless, secrets of preparation of "Muhammad pellets" have been shared. Kefir, which looks like large-curd cottage cheese, grows by division. It ferments milk sugars and proteins, making the yogurtlike drink. When the active metabolism that assures individuality ceases, kefir curds dissolve and die without aging.

After the curds die, kefir individuals become an arbitrary mix of fermenting microbes rather than the specific combination of bacteria and yeast that forms each curd. Like our protoctist ancestors that evolved from symbioses among bacteria, kefir individuals arose from the physical association of 30 different kinds of microbes. These yeasts and bacteria remain together in precise relationships as each divides, maintaining the integrity of the individual curd.

Symbiogenesis led to complex individuals that *can* die (like kefir and most protoctists) before sexuality led to organisms that *had* to die (such as elephants and us). A kefir individual, like any other, requires behavioral and metabolic reaffirmation: component microbial cells that grow too fast or that do not help to make the curd are forced by the others to die. During the course of brewing the beverage, people inadvertently bred for kefir individuality.

Kefir microbes are integrated into kefir curds just as the former symbiotic bacteria became components of our cells. The kefir curd is a new individual more complex than its components. Kefir can no more be made by the "right mix" of chemicals or microbes than can elephants.

Like kefir, we and all other organisms made of nucleated cells, from amoebae to whales, are not only individuals, we are aggregates. For example, plant cells come from ancestors with indigestion. Ancestral translucent swimming cells that acquired green photosynthetic cyanobacteria began as green monsters. From many partly digested cyanobacteria in a hungry protoctist, a new individual, the green alga cell, and ultimately the plant, evolved.

Kefir is a sparkling demonstration that integration processes by which our cells evolved still occur. Kefir also helps us see how the origin of complex new individuals preceded the evolution of programmed death of the individual. Kefir instructs us, by its existence, about how the tastes and choices of one species (ours) influence the evolution of others, the 30 intertwined microbes that became the kefir curd. Although the kefir curd is a complex individual, a product of interacting aggregates of bacteria and fungi, it does not reproduce by sex. Rather the kefir curd, which has no sex life, enlarges by direct growth, division and death of its components. When mistreated by adverse environments, it disintegrates and dies. And, like any live individual, it never returns to life as that same individual.

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