

k25 Obligate-symbiotic mutualism < corals, zooxanthellae; ^{12}C , ^{13}C >

... mitochondria are endosymbionts descended from formerly free-living proteobacteria. For, to those of us interested in both evolution and religion, the confirmation that human and other eukaryotic cells were really bacterial cooperatives (in Whose image?) certainly felt like a double-strength paradigm shift.
—Arndt von Hippel.¹

Insects have integrated bacterial genomes to an extraordinary degree. In many cases, bacteria reside in all the tissues, accumulate in the eggs, and are inherited. Beetles have developed partnerships with an extremely diverse assortment of bacteria; many more kinds live inside their tissues than live in most other groups of animals.
—Lynn Margulis and [her son] Dorion Sagan, 2001.²

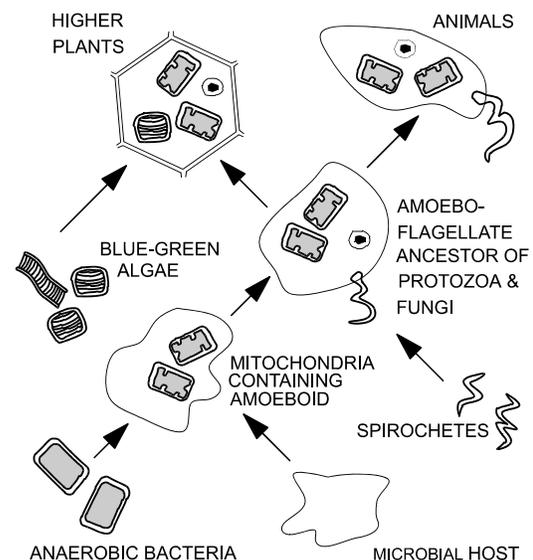
Symbiotic relationships can become obligatory (as say, for some fungi that can live only as partners to other plants, for example the truffle)³ but start opportunistic, as say between reef building corals that live in nutrient poor but sunlit seawater, and zooxanthellae. The zooxanthellae (photosymbiotic plants) live encysted in the transparent flesh of the host coral which provides for them metabolic wastes (with essential nutrients such as ammonia and phosphate). In return the algae provides for the coral needed amino acids, and glycerol (an energy yielding nutrient).⁴

“Whiting” (also called “bleaching”) of the corals can occur when nutrient influxes from upwelling or “pollution” washed in from the land into the coral environment allows the photosymbiotic

Footnote k24.1 Symbiosis (pl. symbioses) is an interactive, intimate, association or merging of two dissimilar organisms (the “host” the larger, the “symbiont” the smaller). Two categories are: ectosymbiosis (the symbiont lives on the body surface of the host, including the inner surface of the digestive tract or the ducts of exocrine glands); and, endosymbiosis (the symbiont lives in the intracellular space of the host). Obligatory symbiosis is when either cannot live without the other. A symbiosis can be: *parasitism* (disadvantageous or destructive to one of the organisms), *mutualism* (advantageous, or often necessary to one or both and not harmful to either), or *commensalism*, (one member of the association benefits while the other is not affected—examples: remora piggyback on a sharks, an epiphyte on a tree, a hermit crab’s needful use of discarded gastropod shells).

Figure k24.1 The symbiotic origin of eukaryotes

Lynn Margulis proposes that eukaryotes are a supercolony of once several separately living microbes. Animals, also fungi, are associations that include mitochondria that had prior existence as purple nonsulfur bacteria. Mitochondria enable eukaryotic cells to carry out aerobic respiration. Plants also contain these organelles and have in addition chloroplasts (which had prior existence as photosynthetic cyanobacteria). The flagella, which some protists have, had a prior existence as spirochetes. In 2004, Maria C. Rivera and James A. Lake can propose that the “eukaryotic genome resulted from a fusion of two diverse [microbial] genomes, and therefore at the deepest levels linking [microbes without a nucleus] and eukaryotes, the tree of life is actually a ring of life. One fusion partner branches from deep within an ancient photosynthetic clade, and the other is related to [archaea]. The eubacterial organism is either a proteobacterium, or a member of a larger photosynthetic clade that includes the Cyanobacteria and the Proteobacteria.”¹⁸



zooxanthellae to decamp (exit-streaming through the coral's open mouth as, in happier times for the coral, do its sperm and eggs) and live independently as algal dinoflagellates (genus *Symbiodinium*). This is an example of obligate-symbiotic mutualism, which is when at least one member (in this case the coral) cannot live without the other.

Algae in the coral animal's flesh promotes the reef. By contrast, algae on the reef outside the coral animal's flesh is destructive. For example, hordes of delicate, nocturnal sea urchins, graze the Caribbean seafloor turf algae. And evidently had for millennia when in 1983 a plague, lethal to just one species of these, namely the black spiny urchin *Diadema antillarum*, by a still-unidentified germ, swept through the Caribbean basin beginning at the Atlantic side of the Panama Canal. Infected urchins lost spines, grew lethargic, and exuded mucus. Any reef hit by the epidemic was devoid of living *Diadema* within 2 weeks. Over the course of 13 months or so, 97 percent die-off of *Diadema*, through 3.5 million square kilometers, is, according to Haris Lessios, "the most extensive ever reported for any marine animal."⁵ Revealed was how dependent the coral reef ecosystem is upon a single species of herbivorous urchins. Without masses of roving *Diadema* present (other echinoderms, as the shorter spined similar looking *Echinometra viridis* anchor to a place), algae, no longer effectively held in check by grazing then blankets any bleached (dead) reefs and prevents its ordinary recovery by larval-coral reseeded. Janet Raloff notes in 2001 that "largely unmowed blankets of greenery cover most of the Caribbean's hard surfaces, including its mostly dead corals. Unless this dense algal cover is cropped, larval corals can't resettle and reclaim reefs built by their dead and dying progenitors."⁶ "Whiting" of coral is when the shell can be seen through the transparent coral flesh when it is depleted in algae. As water approaches 31°C (88 °F), reef-top *Acropora* coral polyps living in Australia's Great Barrier reef expel their algae, which can be a gone-awry survival response (**Footnote k25.1**), and die. Other environmental causes of coral whiting are: changes in solar radiation, reduced salinity, and changes in oxygenation.⁷

Martin Brasier and John Lindsay suggest that 10 million years of consistently scarce nutrients may be needed to make a symbiotic relationship obligatory.

Sea plants tend to absorb more Carbon-12 (¹²C) than Carbon-13 (¹³C). The heavier isotope left in the seawater accumulates in relatively greater amount in chemical marine sediments. So large amounts of ¹³C in the ocean sediment core samples indicates large amounts of ¹²C was at the time in, abundant, plant life. Big fluctuations in the carbon-isotope record are related to mountain building events when erosion accelerates and increasing amounts of washed from the land mineral nutrients fuel sea-plant growth. Between orogenic events, erosion rates fall off, and sea-plant populations decline precipitously. Cores drilled from ocean sediments deposited 1.0-2.0 Ga, now found in north central Australia and described by Brasier and Lindsay in 1998, have unvarying ratios of two carbon isotopes, ¹²C and ¹³C. The implication is of a billion years of tectonic quiescence or, alternatively, of a sustained global rate of orogenesis.⁸

Is it coincidental that the first eukaryotes⁹ appeared near the end of the Mesoproterozoic when ended a billion years duration of constant nutrient level in seawater?

Footnote k25.1 Many coral species live at a range of depths and, under the different lighting conditions, have different communities of symbiotic algae in their flesh. For these, Andrew C. Baker in 2001¹⁰ has found support for a high-stakes survival by bleaching theory, suggested by Robert W. (Bob) Buddemeier and Daphne Gail Fautin in 1993,¹¹ wherein expulsion of in-residence symbionts, now failing to sustain the coral's life, makes way for the moving in of alternative algae better suited to the new environmental conditions.

A proxy often used for past sea-surface temperatures, is the ratio of aragonite strontium to calcium in coral. But in her analyses of the coral *Astrangia poculata*, Anne L. Cohen in 2002 has found that these ratios should always be obtained from layers deposited at night when the algal symbionts will have been inactive. In the day, up to 65 percent of the variation in strontium deposition can be attributed to the algae and not to changes in water temperature.¹²