

The Evolution of Symbiosis

(By Monica R. Steffen—1982)

In past scientific experience it was thought that symbiosis had its place on the outer perimeter of evolution, displaying itself in such bizarre and exotic cases as lichens and cow rumens. It is now being discovered that in fact symbioses are widespread and central to the mainstream of evolution and are essential to existence. This discovery is of primary importance particularly in this day and age when polarity and contention are the guiding forces by which the highest evolved organism, *Homo sapiens*, lives in society. With the potential of human destruction looming dangerously on the horizon, I cannot think of a more crucial time to introduce this concept.

Symbiosis: What it means. The word “symbiosis” was first defined by the Botanist Heinrich Anton de Bary as being “the living together of differently named organisms.” The more current definition is “the association, for significant portions of the life cycle, of individuals that are members of different species.” But, according to Lynn Margulis who is a professor of biology at Boston University, “Neither the general discussions nor the definitions have been very enlightening, nor have they stimulated new research.”

Perhaps looking back to the terms original roots without adding the scientific stipulations and limitations could provide a bit of insight into the essence of the word. Symbiosis comes from the Greek “sym” which means “with” and “bios” which means “life”, so basically the word means “the state of living with.” It is the interdependence of life.

Symbiosis is a peaceful phenomenon as opposed to the two other related forms of interaction, pathogenesis in which one of the organisms is severely damaged, and parasitism in which one partners is gradually debilitated.

According to Margulis, “Symbiotic associations offer their members workable solutions to many of the basic problems of health and survival.” Behavioral, metabolic and develop-mental factors combine to optimize the chances that natural selection act on the symbiotic association rather than on the symbionts as individuals.

Symbiosis: From the very beginning. There has been a revival of ideas with regards to the symbiotic origins of organelles in eucaryotic cells. This has arisen from present-day discoveries of the abundance of microbial symbioses coupled with the recognition that a plant or animal cell contains several remotely related, semi-dependent genetic systems such as the mitochondria and photosynthetic plastids.

Mitochondria, which are found in nearly all protists, fungal, plant, and animal cells, are responsible for generating ATP by oxidizing the molecules obtained as food or produced through photosynthesis. They contain their own genes which are similar to the DNA molecules found in viruses and bacteria, and they also contain their own complex internal membranes.

In cytochrome composition and in other physiological and biochemical respects, mitochondria resemble the free living bacteria of the genera *Paracoccus* and *Rhodospseudomonas* much more so than they do the nucleocytoplasm in which they are found. However, mitochondria do not contain enough genetic material to produce all their own components and proteins and are dependent on the nucleocytoplasm and protein-synthesizing machinery of the cell. Such observations make it possible to believe that mitochondria were acquired as symbionts during the earliest appearance of the ancestral eucaryotic cell, and persist in intimate association with their nucleoplasmic hosts.

Photosynthetic plastids provide yet another interesting example of microbial symbiosis. Not only do chloroplasts and other plastids have their own genetic mechanisms, but they also have a curious double membrane structure. The outer membrane is synthesized according to the instructions of the eucaryotic nucleus; the inner membrane is synthesized according to the instructions of the plastid's own genetic system.

Photosynthetic plastids bear a very marked resemblance in structure, macromolecular chemistry, and function of free-living, oxygen-producing photosynthetic coccoid bacteria. Of particular interest to evolutionary research today are the Prochloron because they have the features of predicted ancestral chloroplasts.

Symbiosis: A problem solver. As mentioned earlier, symbiotic associations provide workable solutions to many of the basic problems of survival. Providing adequate nourishment is one of the problem-solving advantages of symbiosis.

There is a species of green hydra, *Hydra viridis* or *Chlorophydra viridissima*, whose characteristics have been extensively studied. Their green coloration is due to their association with a species of green algae, *Chlorella* that lives within the hydra's gastrodermal cells. As long as there is adequate sunlight, these hydras are able to sustain themselves with the food produced by their photosynthetic symbionts even if outside nourishment is not provided. The closely related white hydras, however, would starve without external provisions.

There are a variety of marine fish, which have developed a symbiotic interdependency with luminous bacteria. The fish provide sanctuary and food for these specialized bacteria, and the bacteria provide these fish with a steady, controllable light source for searching out food in dark waters and for signaling members of the same species.

Even some of our unwanted tenants, the termites, owe their existence to symbiosis. Dry wood and subterranean termites harbor an array of symbiotic bacteria and non-photosynthetic protists in their paunch. These symbionts break down the wood cellulose into forms that the termite can utilize. The termite ingests nourishment for the bacteria, and they, in return, convert these foodstuffs into nourishment for the termite.

Symbiosis also solves the problem of motility and large size for some organisms. Polymastigotes, for example, have a set number of cilia in relationship to the number of nuclei they have per cell. Selection pressure usually acts against an increased number of nuclei and therefore against good motility. In order to overcome this, motile bacteria are often acquired as external symbionts. These bacteria crowd the surface of the polymastigote and beat their bodies in synchrony with the cilia, thus good motility is restored.

Human beings too are about ten percent dry-weight symbionts. Bacteria are housed in the small and large intestines, on the skin, in the mouth, and in the genital tract. Many of these symbionts are responsible for synthesizing important vitamins and for chemically enhancing the digestive process.

As science explores the symbiotic phenomenon, it is becoming more and more evident that it is a common occurrence rather than a rare event, and according to Margulis, "...it is a product of an evolving interspecific relationship."

Symbiosis: The human realization. The species *Homo sapiens* is the highest evolved organism on this planet to date thanks to symbiosis and myriad other forces such as natural selection. Given the evolved human intellect, man has the potential to grasp the essence of his existence, to perfect himself, and to direct himself toward a purpose.

Within the last couple of decades, we have witnessed a knowledge explosion in all areas of science. This scientific period of enlightenment has given us much insight to our existence. It is now time to harmonize this knowledge and direct it toward a universal purpose. Man can no longer afford to continue his exploitive abuse of this knowledge without running the risk of destroying himself.

Man has yet to realize that in order for him to survive as a species he must learn to live symbiotically with his fellow man, with other species of the earth, and with earth itself.

Symbiosis: A tool for learning. Science and religion provide vehicles by which man can realize his potential; unfortunately, they too have yet to be symbiotically united. In essence, science in its pure form and religion in its true sense are one and the same; their main pursuit is that of truth. The problem exists in the vocabularies of the two institutions. Their teachings are the same, but they are speaking two different languages.

Because of this, miscommunication and misunderstandings arise, thus, polarizing the pursuers of the same truth. This polarity is found not only between the school of science and the school of religion, but it is also found within the individual schools. Within the religious institution there are many denominations with their many different beliefs, and those who hold a particular dogma would profess that theirs is the only truth. Within the scientific institution there are many schools of theory and thought, and those who pursue a particular theory in a defined manner without considering other schools of thought and other consequences run the risk of discovering only a half-truth.

It is not that these polarized institutions are all together wrong, for there is much truth in their teachings, but they are representing only a part of the truth and thus are only partly correct in their teachings.

Polarization between and within these institutions serves only to complicate the search for truth. Men of science and those of religion need to strive for a symbiosis of the two institutions; the language barrier must be bridged so those who seek to learn the truth may be taught a whole truth.

Symbiosis: Hope for human society. Our society, both national and global, is suffering from an acute case of the Old Testament's Cain and Abel Syndrome. The two brothers represent two contentious forces. Rather than trying to accommodate one another, they allowed their differences to create bitter resentment. The consequences of this animosity culminated in the demise of one and the long-term suffering of the other. There are many contentious forces acting on the world which set individual against individual, culture against culture, and nation against nation. The consequences of these contentions and our failure to make accommodations are displayed daily in the many Cain and Abel scenarios that color the news media—and looming dangerously on the horizon are the consequences of a major contention between two nations that threatens the existence of all mankind and other life forms.

Perhaps this is the message of the New Testament's Book of Revelation. Taken literally, as many do take the Bible, this writing conjures up all sorts of unimaginable terrors. But if the mystical propositions are reduced to an applicable perspective, the choices it offers and the consequences of each choice may be brought to new light.

Apocalypse (from the Greek "apokalypsis" which means "uncover") may be said to represent the uncovering of the true purpose of our existence, the symbiosis of all nations such that a unified, interdependent world society is created.

Armageddon, the antithesis of apocalypse, may be said to represent the consequences of pursuing a contentious purpose, the maintaining of individual nations such as to perpetuate a divided world.

Unfortunately, we are currently living in a very divided world, a contentious world with a nuclear holocaust impending, and man is still applying his evolved intellect and acquired knowledge to self-serving purposes. He has yet to learn to be accommodating, to become symbiotic. He is still parasitic and sometimes even pathogenic in his relationships to other men, to other forms of life, and to the earth. But even so, there is still hope for mankind; according to Margulis, "...parasitic relationships may become benign and even obligate..." and thus these relationships would become symbiotic.

The laws of love that are taught by many of the world's religions, Christianity to name just one, are the laws of symbiosis. When man learns to become accommodating, when he learns to live interdependently, then would true religion and symbiosis be experienced.

We have seen how symbiotic relationships between organisms have been used to solve problems of survival. Human symbiosis may well be the key to solve many of the problems that face mankind. But in order to take on such grandiose tasks as achieving world peace and feeding the millions of hungry people in this world, we must first learn to be accommodating in our daily existence. We cannot become a symbiotic world society unless we learn to become symbiotic individuals.

It is time for us to realize that we live on a physically finite planet. The material things we borrow from this earth in order to survive are precious and must be shared. Yes, symbiosis is the way.

Footnotes:

1. 4-18 Lynn Margulis, "Symbiosis and the Evolution of the Cell," 1982, Yearbook of Science and the Future, Encyclopaedia Britannica, Inc., 1981, pp. 104-121
2. M. P. Starr, "Bdellovibrio as Symbiont," Symp. Soc. Exp. Biol., 29, 1975, 93-124
3. Lynn Margulis, "The Genetic and Evolutionary Consequences of Symbiosis," Exp. Parasit. Rev., 39, 1976, 277-349
4. Special reference: my father who has given me colorful insights into religion, science and life.