

## Endosymbiotic Theory

### Assignment:

- 1) Read the essay titled "Organelles as Organisms" by Lewis Thomas. Use a dictionary if needed! Highlight what you think are particularly interesting and important ideas. Write notes in the margins or underline key ideas.
- 2) What do you think the main point is in this essay? Do you agree or disagree with the idea?
- 3) What does this essay say about symbiotic relationships?
- 4) Come to class ready to discuss the essay and the ideas presented in this essay.

### *Organelles as Organisms*

by Lewis Thomas

(1) **W**e seem to be living through the biologic revolution, so far anyway, without being upheaved or even much disturbed by it. Even without being entirely clear about just what it is, we are all learning to take it for granted. It is a curious, peaceful sort of revolution, in which there is no general apprehension that old views are being outraged and overturned. Instead, whole, great new blocks of information are being brought in almost daily and put precisely down in what were previously empty spaces. The news about DNA and the genetic code did displace an earlier dogma; there was nothing much there to be moved aside. Molecular biology did not drive out older, fixed views about the intimate details of cell function. We seem to be starting at the beginning, from scratch.

(2) We not only take it for granted--we tend to talk about the biologic revolution as though expecting to make profits from it, rather than a version of last century's industrial revolution. All sorts of revolutionary changes in technology are postulated for the future, ranging from final control of human disease to solutions of the world food and population problems. We are even beginning to argue about which futures we like and which we prefer to cancel. Questions about the merits of generic engineering, the cloning of desirable human beings from single cells, and even, I suppose, the possibility that two heads might actually be better than one, are already being debated at seminars.

(3) So far, we don't seem to have been really shocked by anything among the items of new knowledge. There is surprise, even astonishment, but not yet dismay. Perhaps it is still too early to expect this, and it may lie just ahead.

(4) It is not too early to begin looking for trouble. I can sense some, for myself anyway, in what is being learned about organelles. I was raised in the belief that these were obscure little engines inside my cells, owned and operated by me or my cellular delegates, private, submicroscopic bits of my intelligent flesh. Now, it appears, some of them, and the most important ones at that, are total strangers.

(5) The evidence is strong and direct. The membranes lining the inner compartment of mitochondria are unlike other animal cell membranes, and resemble most closely the membranes of bacteria. The DNA of mitochondria is qualitatively different from the DNA of animal cell nuclei and strikingly similar to bacterial DNA; moreover, like microbial DNA, it is closely associated with membranes. The RNA of mitochondria matches the organelles' DNA, but not that of the nucleus. The ribosomes inside the mitochondria are similar to bacterial ribosomes, and different from animal ribosomes. The mitochondria does not arise de novo in cells; they are always there, replicating on their own, independently of the replication of the cell. They travel down from egg to newborn; a few come in with the sperm, but most are maternal passengers.

(6) The chloroplasts in all plants are, similarly, independent and self-replicating lodgers, with their own DNA and RNA and ribosomes. In structure and pigment content they are the images of prokaryotic blue-green algae. It has recently been reported that the nucleic acid of chloroplasts is, in fact, homologous with that of certain photosynthetic microorganisms.

(7) There may be more. It has been suggested that flagellae and cilia were once spirochetes that joined up with the other prokaryotes when nucleated cells were being pieced together. The centrioles and basal bodies are believed in some quarters to be semiautonomous organisms with their own separate genomes. Perhaps there are others, still unrecognized.

(8) I only hope I can retain title to my nuclei.

(9) It is surprising that we take information like this so calmly, as though it fitted in nicely with notions we've had all along. Actually, the suggestion that chloroplasts and mitochondria might be endosymbionts was made as long ago as 1885, but one might expect, nevertheless, that confirmation of the suggestion would have sent the investigators out into the streets, hallooing. But this is a sober, industrious field, and the work goes on methodically, with special interest just now in the molecular genetics of organelles. There is careful, restrained speculation on how they got there in the first place, with a consensus that they were probably engulfed by larger cells more than a billion years ago and have simply stayed there ever since.

(10) The usual way of looking at them is as enslaved creatures, captured to supply ATP for cells unable to respire on their own, or to provide carbohydrate and oxygen for cells unequipped for photosynthesis. This master-slave arrangement is the common view of full-grown biologists, eukaryotes all. But there is the other side. From their own standpoint, the organelles might be viewed as having learned early how to have the best of possible worlds, with least effort and risk to themselves and their progeny. Instead of evolving as we have done, manufacturing longer and elaborately longer strands of DNA, and running ever-increasing risks of mutating into evolutionary cul-de-sacs, they elected to stay small and stick to one line of work. To accomplish this, and to assure themselves the longest possible run, they got themselves inside all the rest of us.

(11) It is a good thing for the entire enterprise that mitochondria and chloroplasts have remained small, conservative, and stable, since these two organelles are, in a fundamental sense, the most important living things on earth. Between them they produce the oxygen and arrange for its use. In effect, they run the place.

(12) My mitochondria comprise a very large proportion of me. I cannot do the calculation but I suppose there is almost as much of them in sheer dry bulk as there is the rest of me. Looked at in this way, I could be taken for a very large, motile colony of respiring bacteria, operating a complex system of nuclei, microtubules and neurons for the pleasure and sustenance of their families, and running, at the moment, a typewriter.

(13) I am intimately involved, and obliged to do a great deal of essential work for my mitochondria. My nuclei code out the outer membranes of each, and a good many of the enzymes attached to the cristae must be synthesized by me. Each of them, by all accounts, makes only enough of its own materials to get along on, and the rest must come from me. And I am the one who has to do the worrying.

(14) Now that I know about the situation, I can find all kinds of things to worry about. Viruses, for example. If my organelles are really symbiotic bacteria, colonizing me, what's to prevent them from catching a virus, or if they have such a thing as lysogeny, from conveying a phage to other organelles? Then there is the question of my estate. Do my mitochondria all die with me, or did my children get some of mine along with their mother's; this sort of thing should not worry me, I know, but it does.

(15) Finally, there is the whole question of my identity, and more than that, my human dignity. I did not mind it when I first learned of my descent from lower forms of life. I had in mind an arboreal family of beetle-browed, speechless, hairy sub-men, ape-like, and I've never objected to them as forebears. Indeed, being Welsh, I feel the better for it, having clearly risen above them in my time of evolution. It is a source of satisfaction to be part of the improvement of the species.

(16) But not these things. I had never bargained on descent from single cells without nuclei. I could even make my peace with that, if it were all, but there is the additional humiliation that I have not, in a real sense, descended at all. I have brought them all along with me, or perhaps they have brought me.

(17) It is no good standing on dignity in a situation like this, and better not to try. It is a mystery. There they are, moving about in my cytoplasm, breathing for my own flesh, but strangers. They are much less closely related to me than to each other and to the free-living bacteria out under the hill. They feel like strangers, but the thought comes that the same creatures, precisely the same, are out there in the cells of sea gulls and whales, and dune grass, and seaweed, and hermit crabs, and further inland in the leaves of the beech in my backyard and in the family of skunks beneath the back fence, and even in that fly on the window. Through them, I am connected; I have close relatives, once removed, all over the place. This is a new kind of information, for me, and I regret somewhat that I cannot be in closer touch with my mitochondria. If I concentrate, I can imagine that I feel them; they do not quite squirm, but there is, from time to time, a kind of tingle. I cannot help thinking that if only I knew more about them, and how they maintain our synchrony, I would have a new way to explain music to myself.

(18) There is something intrinsically, good-natured about all symbiotic relations, necessarily, but this one, which is probably the most ancient and most firmly established of all, seems especially equable. There is nothing resembling predation, and no pretense of an adversary stance on either side. If you were looking for something like natural law to take the place of the "social Darwinism" of a century ago, you would have a hard time drawing lessons from the sense of life alluded to by chloroplasts and mitochondria, but there it is.

