uniformly throughout space, or else a cosmological constant term in Einstein's equations to provide the required source of energy density in what is equivalent to an energy density of the vacuum.

A delightful essay on entropy demolishes pseudoscientific overuse of the second law of thermodynamics. Metaphors are fine, but applications to society and even biology seem hopelessly flawed. It is just as well that someone has challenged the propagator (who else but Jeremy Rifkin?) of such statements as "If love were antientropic, it would be a force in opposition to becoming, for the entropic flow and becoming go hand in hand," or "The governing principle of a low entropy world view is to minimize energy flow . . . a low entropy society deemphasizes material consumption," or again, "New genetic technologies, like recombinant DNA, might greatly increase the matter energy flowing through the system, just as the first industrial revolution did with renewables," or to balance this, "The practice of meditation is designed to slow down the wasteful expenditure of energy." Somewhere along the way, "entropy" and "energy" have gotten hopelessly confused, but this is the least of one's worries: after all, as Rothman notes, Clausius said their meanings are nearly identical. Nearly, but not quite: that ultimately is the distinction between science and pseudoscience.

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Genetic Structures

The Molecular Biology of Plastids. LAWRENCE BOGORAD and INDRA K. VASIL, Eds. Academic Press, San Diego, CA, 1991. xxvi, 340 pp., illus. $109. Cell Culture and Somatic Cell Genetics of Plants, vol. 7A.

DNA molecules, like organisms, have an evolutionary history that can be read by comparative studies of their structure. These studies find their ultimate expression in the analysis of genomes that have been completely sequenced in several different species, for in these cases all of the available evolutionary information has been obtained and the investigator can focus on interpreting it. Plastid genomes are a notable success story, for their structure has illuminated the evolutionary history of photosynthetic organisms and provided insights into evolutionary mechanisms. Thus it is entirely appropriate that the term "molecular biology" as used in the title of this book includes evolutionary analyses as well as the study of plastid DNA replication, transcription, and translation.

Appropriately, the book begins and ends with evolution. Palmer's review of the gene content and structure of the chloroplast chromosome is thorough, thoughtful, and authoritative. A fairly detailed picture of the evolution of the plastid genome is emerging now that the chloroplast genomes of a number of plants and several algae have been largely or entirely sequenced and others thoroughly mapped. The transfer of genes from chloroplast to nucleus is well documented, and a picture of the evolution of introns is emerging. Mechanisms of these and other evolutionary changes in genome structure are now being examined by comparative and evolutionary studies. Gray concludes the volume with a review of information and ideas about the early evolutionary history of chloroplasts. Their origin from cyanobacteria-like endosymbionts is well established; now the intriguing question is how many separate endosymbiotic events occurred. Remarkably, it appears that the chloroplast of the cryptomonad algae is derived from a eukaryotic symbiont rather than a prokaryote. Together, the chapters by Gray and Palmer constitute the best available review of chloroplast genome evolution. The evolution of gene sequences, as opposed to genome structure, is treated only cursorily.

In between these chapters on evolution are seven chapters on molecular-level phenomena. Two of these review the properties of the plastid envelope membranes and the transport of proteins into plastids. The great majority of plastid proteins are coded by nuclear genes and synthesized on cytoplasmic ribosomes, and hence must be targeted to the plastids. At the conclusion of their review, Berry-Lowe and Schmidt express disappointment that intensive study in many labs has failed to provide useful generalizations about the important features of transit peptides and their processing. Genetic engineers will be glad to know that a transit sequence from one gene can sometimes assist the import of another gene, but there are no clues about how to improve the process or why some combinations don't work.

Replication, transcription, and translation of plastid DNA and the structure of tRNA and rRNA genes are the subjects of five chapters. There is some overlap, especially with respect to transcription, but surprisingly little given that each chapter has different authors, and the net result is thorough and critical coverage. The plastids have been a great source of novelty and puzzles for molecular biologists. An example is the remarkable case of the chloroplast RNA polymerases. There is a well-characterized soluble polymerase with subunits coded by four different *rpo* genes. But these genes and their protein products show surprising evolutionary variability in size for presumably essential proteins. There are hints that there may be more than one RNA polymerase, but no other plastid genes have been found to code for them. Moreover, the *rpo* genes are missing from the plastid DNA of a nongreen parasitic plant, which is transcribed nevertheless. Other intriguing puzzles include the transsplicing of exons from separate transcripts and the trimming of the 3′ ends of transcripts. The chapter by Sugiura in which these phenomena are described is entirely too brief, at least as tantalizing as it is informative.

Gillham, Boynton, and Harris review the transmission genetics of chloroplast genes in plants and the alga *Chlamydomonas*. Genetic analyses have not played as large a role in the dissection of molecular processes in plastids as they have in nuclear genomes, but this is changing as *Chlamydomonas* acquires the kind of molecular genetic versatility typified by yeast and *Drosophila*. Plants are much less useful for plastid genetics because of the scarcity of biparental inheritance and recombination. Gillham and Boynton correctly emphasize that there are very different modes of inheritance in different species of plants: strictly maternal, strictly paternal, and biparental, in which plastid genes from both parents are seen in the progeny, but often in different individuals. Thus the rule is uniparental inheritance, not maternal inheritance. The authors meticulously review the multitude of deterministic processes that predispose inheritance toward one parent. Unfortunately they neglect stochastic mechanisms such as random replication, turnover, gene conversion, and random partitioning of genomes between embryonic and extraembryonic tissue. As a result their models cannot explain some important features of organelle gene inheritance, especially the various patterns of biparental inheritance seen most strikingly in *Chlamydomonas* and *Pelargonium*.

Although this book is part of a series entitled Cell Culture and Somatic Cell Genetics, intended to focus on the use of these techniques in biotechnology, much of it has no apparent bearing on genetic engineering and plant cell culture. In fact, where there are implications for applied work, these are usually not pointed out. This volume displays careful editorship, with lucid writing in remarkably uniform style and few production errors. The information content is too dense for it to serve as an easy introduction to chloroplasts. But for readers with some

background, or for specialists, the book is an excellent reference and update on fields outside their own. I eagerly await a future volume on plant mitochondria.

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