Complexity in Organismal Evolution

Stuart A. Newman

Throughout the last half of the twentieth century there were expectations that increased knowledge of genes and their structure would provide a "blueprint" for the complex traits of organisms. As detailed information accrued, however, it became increasingly clear that the regularities of embryonic development and the potential of organisms to evolve were written not in the genes, but in complex systems in which the genes and their products are just subsets of components. Among the factors beyond the gene that needed to be taken into account for a satisfactory understanding of multicellular form and pattern were the physics and chemical dynamics of viscoelastic "excitable media." Most of these nongenetic determinants of organization are not specific to living systems but are generic to all materials of a certain spatial scale and chemical richness. This newer picture implies that much genetic evolution since the early Cambrian period occurred so as to reinforce and routinize the development of structural motifs (layers, segments, tubes, appendages) that originated by more spontaneous physical means in earlier times. Thus, rather than being dispositive in the determination of morphological phenotype, a large portion of the genetic and biochemical complexity of modern organisms serves a stabilizing and supporting function. This view of organisms as complex material systems in which not only genotypes and phenotypes have evolved, but the relationship between them has done so as well, has broad implications for understanding the nature of living systems and their relation to the nonliving world. By rejecting genetic essentialism and determinism it can also illuminate philosophical debates around the natural/artifactual distinction that have accompanied recent applications of biotechnology.