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Genome Evolution in the 21st Century

JAMES SHAPIRO, University of Chicago

Assume no previous theories about genetics and evolution. What conclusions would we draw from molecular data (e.g. genome sequences)? We start from basic principles of cellular information processing: cells behave cognitively using signal transduction networks; signal transduction involves weak noncovalent interactions; allosteric properties of biomolecules; multivalent storage of information in DNA sequences and nucleoprotein complexes; inertness of naked DNA. Genome informatics thus requires formation of nucleoprotein complexes. Complex formation requires generic repeated signals in the DNA; repetition also permits cooperativity to stabilize weak interactions. DNA is a functional structural component of nucleoprotein complexes, not a passive data tape. Specificity in DNA nucleoprotein complex formation involves combining multiple generic signals and/or sequence recognition by small RNAs. Novel combinations of generic signals and coding sequences arise in genomes by iteration and rearrangement. Cells possess natural genetic engineering functions that actively restructure DNA molecules. These internal DNA remodeling functions act cognitively in response to internal and external inputs. They operate non-randomly with respect to (1) the types of new structures produced and (2) the regions of the genome modified. Whole genome sequence data increasingly documents the historical role of natural genetic engineering in evolutionary changes. Basic principles of cellular molecular biology and DNA function lead to a complex interactive systems view of genome organization. This view incorporates different DNA components found in sequenced genomes. Regulated cellular natural genetic engineering functions permit genomes to serve as Read-Write information storage systems, not just Read-Only memories subject to accidental change. These 21st Century conclusions are most compatible with a systems engineering view of the evolutionary process.