Books

Gene Activity in Early Development

Third Edition

by Eric H. Davidson

Academic Press, Inc., 670 pages

IF MODERN DEVELOPMENTAL BIOLOGY can be said to have a central, unifying principle, it is the theory of differential gene activity: As development proceeds, the many cellular descendants of the zygote take on very different forms and functions by virtue of their differential utilization of the same genomic information. Thus, ectodermal cells and mesodermal cells contain the same complement of genes in their DNA but synthesize different (though overlapping) subsets of the total number of proteins encoded therein. If we ever arrive at a clear understanding of the wondrous process of development, it will consist in large part of a knowledge of both the causes and consequences of differential gene activity.

Gene Activity in Early Development is an attempt to provide a coherent description of the current state of our understanding of this problem and is consequently a very ambitious undertaking. This is all the more true because the interval between the second (1976) edition and the present one has been characterized by nothing less than an explosion of information (if not elucidation) relevant to the subject of this book. My copy of the second edition weighs 1,026 grams; the third, while larger, still weighs only 1,456 grams. It is safe to say that the sheer amount of data has increased by a vastly greater proportion, so to make sense of it in a book of manageable size clearly required a selective, critical, and synthetic approach. Given the added difficulty of the task, it is remarkable that this new volume is such a success.

The main concern of the book (as of developmental biology today) is the study of development at the molecular level. Yet the presentation and evaluation of the biochemical results is skillfully interwoven with the work of both early and modern embryologists, particularly regarding the mapping of cell lineage and cell fate. This serves to remind us that the developmental processes we seek to understand are ultimately cellular and organismal events, and thus provides the proper biological context in which to view the molecular analysis of development. The author's ability to organize and illuminate the very diverse embryology literature is especially apparent in the brilliant last chapter, which considers the evidence for localization in the egg cytoplasm of "morphogenetic determinants," substances with the capacity to direct the developmental fate of the cells that inherit them.

Two other important aspects of the book's approach are unique and must be described. There is an emphasis throughout on a *quantitative* understanding of early gene expression. The synthetic activities of the mother and the embryo are here considered in terms of numbers of RNA transcripts completed per second, or numbers of molecules per cell of a particular protein (with many of these values calculated, not just drawn, from the published data). This emphasis reflects the not yet widespread understanding that a successful description of embryogenesis must be able to account for its quantitative, as well as its (perhaps more obvious) qualitative aspects.

The main strength of the book, however, lies in the frequent comparison and synthesis of experimental results from diverse developmental systems — from snails to frogs to worms to flies to mice. We are provided with very satisfying insights into the different ways that a specific developmental problem has been solved during the evolution of various phylogenetic branches, each solution reflecting peculiar features of those animals' biology. And, of course, we are treated to the occasional generalization: In all systems for which there is evidence, the set of zygotic genes active in the midstage embryo consists largely of those used by the mother during oogenesis to provide the oocyte with its store of maternal transcripts. Such results are the molecular counterparts to the pictures found in nearly every embryology text defying the reader to tell the human embryo from the chicken embryo from the frog embryo.

The back of the book has a couple of features new to this edition. The mathematical treatment of three topics (nucleic acid reassociation kinetics, measurement of RNA transcript abundance, and RNA synthesis and turnover kinetics) has been gathered into three concise appendices. A pouch attached to the inside back cover contains an unusual treat — large-scale embryonic cell lineage diagrams from the sea urchin and the nematode *c. elegans.* (By the way, it pays to note how the nematode diagram is folded *before* examining it, unless you plan on tacking it on your wall.)

The book fills a critical need at an appropriate juncture. Developmental biology has been revolutionized of late by the application of molecular methods of analysis, particularly the techniques encompassed by the term recombinant DNA. The appearance of these powerful new experimental tools has led to the generation of large amounts of exciting new information; we are beginning to attack questions that were formerly unapproachable. But such a state of affairs makes even more acute the need for a critical synthesis of the results, to give as coherent a picture as our ignorance allows. It is essential that this synthesis maintain a broad perspective, drawing on all lines of evidence and not just the new, fashionable ones. Above all, we'd like to be introduced to new ideas and fresh ways of thinking about embryogenesis.

Gene Activity in Early Development represents an eminently successful attempt to accomplish the task. It is inevitably a somewhat personal perspective, for a work of this kind involves countless choices of interpretation and emphasis. But all who read the book, undergraduate and senior scientist alike, will find themselves well served by this unique and particularly insightful view of development. □

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To Utopia and Back
The Search for Life
in the Solar System

by Norman H. Horowitz

W.H. Freeman and Company,
168 pages

PROFESSOR HOROWITZ'S short book, handsome, illustrated, with an index, bibliography, and glossary, is subtitled *The Search for Life in the Solar System.* This carries an emotional overtone mirroring the baffled scientific effort of the last century to find a nearby, inhabited world. Apparently, human beings do not want to be alone in a cold, empty cosmos. Horowitz, an eminent biologist, was central in the Viking Lander biology experiments, two small, elaborate, and successful laboratories that reached Mars in 1976. The second Lander arrived on a rock-covered plain called Utopia Planitia, but the environment proved far from utopian. There were no Edgar Rice Burroughs warrior queens and heroes, no remnants of a dying sophisticated civilization. It was cold, and there was no water. There were jagged rocks, windblown, coarse, reddish dust, sometimes morning frost — and no life.

The book is written for an intelligent reader; what one can absorb depends on one's background. There is much to feast on, although I find most articles on biology at the *Scientific American* level as difficult as those on particle physics. Horowitz describes the nature of life and the implications for its origin. If life is to develop spontaneously, and once, from complex, organic, but non-living molecules, its environment must have narrowly specified temperature, force of gravity, and chemical composition. Most important is a liquid solvent, water on the Earth, whose physical properties set the temperature and ambient gas pressure. He disposes of exotic solvents and of life based on compounds other than carbon, C.

Biology and astrophysics have progressed far this century; astronomers find a fortunate rightness in the fact that life is carbon-based. C was almost certainly the first chemical element synthesized in the nuclear furnaces of the stars, from hydrogen, H, and helium, He. The stars are roughly 98 percent H and He; C makes up much of the balance. The building blocks of life are nucleic acids (DNA or RNA), which carry the information, and proteins (which are made of 20 amino acids). Of the amino acids, which polymerize to form complex, three-dimensional compounds, 18 contain only H, C, nitrogen, N, and oxygen, O; two have sulfur. In contrast, the Earth (and probably Mars) has 62 percent iron, magnesium, and silicon, and only 0.05 percent H, C, N. The average protein is 49.6 percent H, 31.6 percent C, 9.7 percent O, 3.8 percent N (by numbers of atoms). Living things concentrate normally volatile gases on Earth enormously. Their cosmic composition encourages a theory that life can evolve from non-biological compounds of H, C, N, O, given the right temperature, a gravity sufficient to retain some atmosphere, and liquid water, the most abundant universal solvent. Horowitz outlines the Oparin-Urey theory that life evolved spontaneously in a water solution of organic compounds exposed to a reducing (not oxidizing) atmosphere. Life developed just once — and not long after the Earth settled down.

Not all popularization of astronomy was in harmony, alas, with this picture. Horowitz tells the lurid but unfortunate story of Percival Lowell, of the Boston Lowells. At his own observatory in Flagstaff, Lowell over-interpreted fleeting glimpses during the best seeing of Martian surface patterns and colors into a fantasy (in books published from 1898 to 1908) of seasonal growth of vegetation, caused by flow of water in canals from the water-ice cap. Most of his contemporaries did not believe in the canals, but some planetary astronomers followed Lowell 50 years too long and believed in the water. They favored H_2O over CO_2 ice caps. They misinterpreted measured polarization of scattered light to give too dense and wet an atmosphere. Only in 1965 did astrophysicists (at Caltech and JPL) correctly interpret the spectrum of Mars as indicating an atmosphere dominated by CO_2, much too thin for liquid water to exist or for parachutes to land. Thus died the canals and the fading Martians. I have never liked science fiction; I showed Mars to Wernher von Braun through the 200-inch telescope at Palomar about 1965. He looked at the blurred, dancing image and said, "Is that all?" Even under the best seeing from Earth, the smallest detail visible is 150 km in diameter. Physical conditions are studied best with spectrograph, bolometer, and photometer, and Mars is, at closest, 55 million km distant. Its surface and atmosphere must be studied close up.

Horowitz's chapter 7 describes the biology experiments on the Viking Landers; it is called "Where are the Martians?" The atmosphere proved to be largely CO_2 at a pressure one percent of that on Earth with a tiny amount of water vapor. The experiments operated successfully and were sophisticated; they would have detected carbon-based organisms. Surface samples scooped up into the gas-chromatograph mass spectrometer revealed that carbon compounds were 1,000 times less abundant than in our desert soil. The Martian surface had at most a few parts per billion of organic matter; some meteorites have much more. Even the residues of such meteoritic dust have been destroyed on Mars, probably by the chemical activity of the soil. A biological experiment incubated Martian soil with "nutrients," which terrestrial micro-organisms would use, to detect the effluvia from Martian cousins. This gas-exchange experiment wet soil and nutrients and detected unexpectedly large amounts of released O_2. This is ascribed to chemically active oxides or peroxides in the soil.

The labeled-release experiments used simple organic compounds (including amino acids), such as are formed easily on Earth, but labeled with radioactive C. A nutrient was attacked by the soil, releasing radioactive CO_2; a second trial, presumably after soil peroxide had been used up, gave no release. Had micro-organisms been present in the soil, they would have survived to eat and produce more radioactive CO_2. The pyrolytic-release experiment attempted to duplicate Martian environment and to study absorption of feed-gases, radioactive CO and CO_2, into the Martian soil. If anything, it detected iron minerals, expected in red dust. But Martian Landers gave similar results — soil chemically active, no living organisms, and no organic carbon compounds. Horowitz describes and pictures one place in Antarctica as cold and dry as Utopia Planitia on Mars and lacking mirco-organisms. Mars is not utopia but a cold desert.

Mars is not the abode of life, nor is Venus that of love; one is too cool and has too little atmosphere, the other too hot and has too much. Our solar system is not the only one; other planets near other stars may be "just right." It will be a long time until they are explored biologically; meanwhile the emphasis will be on detection of radiofrequency communications, if other organisms are talkative. The Viking experiments were a great success in many ways; the Orbiters transmitted 50,000 pictures of the surface, some with resolution of 20 meters. They show great extinct volcanoes 27 km high and impact craters 100 km wide. There are lava ridges and flows, groups of deep canyons 700 km long, wider and deeper than our Grand Canyon. Most unexpected are runoff and outflow channels almost certainly cut by water (which no longer exists) and more than 3.5 billion years old. "Where has the water gone?" is a question parallel to "Where are the Martians?" Mars is for planetary scientists now but was our best chance to study other biologies. Norman Horowitz has beautifully explained that quest. □

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