Developmental Genetics

Insect Development. Papers from a symposium, London, Sept. 1975. P. A. LAWRENCE, Ed. Halsted (Wiley), New York, 1976. x, 230 pp., illus. $25. Symposia of the Royal Entomological Society of London, No. 8.

P. A. Lawrence writes in the foreword to this book that "developmental biology, after about 30 years in the doldrums, is beginning to move again. New work on insects is one of the main reasons for this fresh start."

Although many developmental biologists will take exception to the first of these statements and at least some to the second, most would agree that the field, especially the study of the developmental genetics of insects, is at present a very lively one. This is apparent not only from the book reviewed here, but also from the number of review articles, symposium presentations, and books on the subject that have appeared during the past five years or so.

The utilization by an increasing number of biologists of the imaginal disk system of *Drosophila* for developmental studies has contributed greatly to this burgeoning activity, and over half the chapters in this book deal at least in part with studies of disk derivatives. Such studies are not really new; rather they represent the natural evolution of ideas and the increasingly sophisticated use of methods developed during the 1930's and '40's. Their intellectual lineages can easily be traced by anyone familiar with the literature.

It has long been recognized that the insect integument provides an excellent model for studying such general processes as cellular differentiation and the control of developmental patterns. In higher Diptera (and some other holometabolous insects), the primordia that eventually give rise to the complex cuticular structures of the adult body, the eye, and the internal genitalia other than the gonads become sequestered from larval cells early in embryogenesis (Gehring, Nöthiger, Schneiderman; this volume), giving rise to simple epithelial sacs, the imaginal disks, each with a distinctive location and morphology, which undergo extensive growth and complex foldings during the larval stages. Eversion and differentiation of the disks take place during the pupal stage. Larval imaginal disks, or fragments of them, implanted in host larvae will undergo metamorphosis and differentiation in concert with the host.

Conversely, disks implanted in adult females cannot differentiate because of the lack of appropriate hormonal stimulation but do continue to undergo cellular multiplication. Taking imaginative advantage of this dual culture system, Hadorn (*Dev. Biol.* **7**, 617 [1963]) devised a method for long-term culture and cloning of disk cells. Because each disk produces a number of distinctive structures, even small, grossly distorted fragments, often consisting of only a few cells (Illmensee, Schneiderman; this volume), can be identified as to disk, and even exact region, of origin. Added to these useful culture methods and the distinctive nature of disk products, small or large groups of cells can be genetically marked by the induction of somatic crossing-over or by chromosome elimination to produce gynanders. Thus the ingenious investigator can carry out a kind of genetic surgery, exquisite in the precision with which the fates of individual cells can be followed (Schneiderman, this volume). The development of simple, effective techniques to bring about large-scale chemical mutagenesis, coupled with effective, and often highly inventive, screening methods, now permits the isolation of mutants that affect almost any structure, stage, or developmental event. For example, temperature-sensitive mutants that affect the cell cycle and cell viability have been isolated and used to control the contributions made by specific cell populations to adult structures (Schneiderman, this volume).

A milestone in developmental biology was the development by Briggs and King in the 1950's of methods for nuclear and cytoplasmic transplantation in amphibian embryos. Similar methods have at last been developed for *Drosophila* (Illmensee, Schneiderman; this volume), and the general results—the totipotency of nuclei at least through the gastrula stage and the ability to cure certain maternal defects by cytoplasmic transplantation—parallel those in Amphibia. These techniques also hold promise for an eventual understanding of how specific cytoplasmic elements may control genetic activity.

In a series of collaborative studies, Illmensee and Mahowald have shown that the posterior polar plasm of oocytes or cleavage-stage embryos (the region associated with differentiation of germ line cells at the blastoderm stage), when injected into ventral or anterior regions of cleavage stage embryos, leads to the formation of cells with the morphology of these primordial germ cells. More significantly, when such ectopically formed pole cells are transplanted into the posterior region of a second host at the blastoderm stage, they can become incorporated into the gonad and there form functional germ cells. Experiments now in progress in Mahowald's laboratory are aimed at isolating specific components of the posterior cytoplasmic fraction so they can be tested by the transplantation technique for their potential to give rise to germ-cell determination.

Given the obvious advantages presented by the methods available to the developmental geneticist, what major contributions have been made by developmental genetic studies to our understanding of general developmental problems? Schneiderman, in his excellent and wide-ranging review, touches at least briefly on most of the major areas of active investigation, including some reported on in greater detail elsewhere in the volume. It is apparent that genetic studies have provided considerable refinement and more exact temporal and spatial definitions of some important formal concepts, such as pattern formation and positional information. One intriguing finding that has emerged from these studies is that at least three distinct but clearly related developmental events—determination, transdetermination, and compartmentalization—take place, not in individual stem cells, but in small groups of cells (termed "polyclones" by Crick and Lawrence, *Science* **189**, 340 [1975]) that cell lineage studies have shown are not necessarily directly related. Distinctions have been made between the heritable determination of a group of cells to form a particular disk (or disks—Gehring, this volume), and the more labile developmental potential of cells within the disk primordium (specification) that enables them to "read" their position and to respond to changing information. French, Bryant, and Bryant have used these concepts to formulate an interesting model that "accounts formally and in a simple and unified way for the kinds of developmental regulation seen in. . .both vertebrates and invertebrates" (*Science* **193**, 969 [1976]). (Experimental testing of this model is discussed by Schneiderman; see also the chapter on regeneration of the cockroach leg by Böhn.) One of the most interesting formal concepts to originate directly from recent studies on insects is that of compartmentalization. Garcia-Bellido observed during development of the wing in *Drosophila* that sharply defined regions or compartments become established that have borders in exactly the same place in all individuals. Once cells have become committed to a compartment, they do not cross into another. Similar compartments have been

defined within the abdominal segments of the milkweed bug, *Oncopeltus*. On the basis of these findings, Lawrence and Morata (this volume) have developed the "compartment hypothesis" as a conceptual framework for approaching several important questions: for example, how genetic information becomes translated into a three-dimensional pattern and how size and form are controlled.

Some hope of understanding the nature of developmental events at the cellular and molecular level has been provided by the studies of germ cell determination and by studies, reviewed in this volume by Kalthoff, of anterior morphogenetic determinants in eggs of the chironomid *Smittia*. It is possible, by experimental intervention, to alter cytoplasmically located developmental information in the anterior egg region so that the normal segmental pattern of head, thorax, and anterior abdominal segments is replaced by an additional set of posterior segments arrayed in mirror-image symmetry. The most effective and reliable method for producing these double abdomen embryos is ultraviolet irradiation of a very small region at the anterior end of the egg prior to blastoderm formation. That the morphogenetic agents might be nucleic acid protein moieties was first suggested by the action spectrum for induction of the monster embryos and by the photoreversibility of the effects of ultraviolet irradiation. Now it has been shown that the application of ribonuclease to the anterior end by microinjection produces double abdomen embryos (Kandler-Singer and Kalthoff, *Proc. Natl. Acad. Sci. U.S.A.* **73**, 3739 [1976]). Thus it is speculated that in *Smittia*, and perhaps also in the germ cell determinants (Mahowald, *J. Exp. Zool.* **176**, 345 [1971]), cytoplasmic masked messengers, in the form of ribonucleic phosphate particles laid down during oogenesis, provide localized information controlling specific differentiative or determinative events.

Other chapters in this volume deal with rather diverse subjects. Sander provides a useful review of studies, mostly from German laboratories, of the wide variety of morphogenetic movements during early embryogenesis and lists commercially available films of embryonic development in a number of insect species. It is apparent that if we are to understand the bases of these interesting movements of both the yolk system and embryonic cells more detailed analyses at the cellular and subcellular levels are badly needed. There is an interesting and stimulating discussion by Shelton of the relation of the development of the compound eye, a structure almost crystalline in its organization, to a number of general developmental issues; included are some fascinating observations of differences in growth cone structure in different regions of the brain. Whittle surveys the kinds of developmental problems that can be analyzed by using mutants that affect a single structure (in this case the wing), an approach first used by Waddington in 1939. Wigglesworth reviews his extensive studies of juvenile hormone and cuticular pattern formation. His chapter is distinguished by an interesting discussion of the characteristics of determination at the cellular level in *Rhodnius*. In a final chapter that seems somewhat out of context with the rest of the volume, Ashburner and Richards present their recent studies of induced puffing in the polytene chromosomes of *Drosophila*.

The book is not comprehensive in its coverage, there is some unevenness in that some papers are broad general reviews and others are limited to the author's own studies, and there are some incorrect literature citations. There is also some overlap with articles published elsewhere. The subject has currently become so popular that it is in some danger of overexposure, particularly since the cast of authors reviewing the work remains much the same. Indeed, it is perhaps surprising that some of them have managed to find something new to say in this volume.

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Advances in Cell Biology

Cell Motility. Papers from a symposium. R. GOLDMAN, T. POLLARD, and J. ROSENBAUM, Eds. Cold Spring Harbor Laboratory, Cold Spring Harbor, N.Y., 1976. Three books, illus. Book A, Motility, Muscle and Non-Muscle Cells. xiv pp. + pp. 1–456 + index. Book B, Actin, Myosin and Associated Proteins. xiv pp. + pp. 457–840 + index. Book C, Microtubules and Related Proteins. xiv pp. + pp. 841–1374 + index. $75. Cold Spring Harbor Conferences on Cell Proliferation, vol. 3.

These three volumes effectively demonstrate the change in emphasis that has taken place in research on cell motility in recent years. Until about ten years ago, the main emphasis was on the role of microtubules because they were the major component of such motile organelles as cilia and flagella and because the discovery of cytoplasmic microtubules suggested that microtubules might have a more general role in cell motility as well. Particular interest was focused on trying to find the mechanism of chromosome movement in mitosis, a classical problem that seemed much closer to solution when microtubules were found to be the major fibrillar component of the spindle. Although an equally visible and impressive form of cell movement occurs in amoebas and similar cells, it was considered, for reasons now perhaps less clear, to be less likely to lead to a generalized model of cell motility, even though the involvement of the muscle proteins actin and myosin in amoeboid motion had already been suggested.

Since that time, the working out of the sliding mechanism of ciliary and flagellar movement has provided one of the more elegant examples of the effectiveness of a combined ultrastructural and biochemical attack on a problem in cell biology, and the mechanism of the assembly of cytoplasmic microtubules from the tubulin monomer has become both more clear and more complicated. Assembly of microtubules in vitro is now possible, and the process seems similar to that in cells, where rapid assembly and disassembly of microtubular structures are commonly observed.

While these studies of microtubules were progressing, our view of actin and myosin was changing and they were generally coming to be considered to be not specialized proteins of highly differentiated muscle, but proteins common to most eukaryotic cells. This change came about primarily as the result of two events—the convincing demonstration that "actinlike" and "myosinlike" proteins could be isolated from the amoeboid Myxomycetes by a modification of the methods that had been employed in studying muscle and the demonstration that the enzymatic myosin fragment heavy meromyosin could be used specifically to identify (and localize) actin in cells by electron microscopy. This latter technique was used to demonstrate that actin is present in most cell types, and, more recently, immunofluorescence has shown that other muscle proteins are also common in cells. These results have encouraged the biochemical preparation of muscle proteins from a variety of cell types, and the development of the field can be seen in the change in terminology from "actinlike" and "myosinlike" to "actin" and "myosin" and, more recently, in the study of slight differences in actin and myosin from different sources.

The papers presented at this sympo-