Justifications

At the Heart of the Bomb. The Dangerous Allure of Weapons Work. DEBRA ROSENTHAL. Addison-Wesley, Reading, MA, 1990. xii, 244 p. $18.95.

In the modern Western myth, scientists are imperfect gods. When they yield to hubris—when they mistake the goal of mastery over the natural world for an invitation to power—they fall heroically; hence Faust, Frankenstein, and, depending on whom you talk to, Oppenheimer. Now, at the waning of the Cold War, may be an opportune time to discard that myth. Edward Teller, perennial contender for Oppenheimer's statesman role, looks increasingly like a scientific Willy Loman. NASA's non-epic failures have taken much of the romance from the exploration of space. We are shocked by news of the cavalier disposal of waste from the nation's nuclear weapons plants. All of this is not to indict individual scientists but to call into question the contemporary institutional structure of science, particularly when it claims to operate in the service of public policy.

Debra Rosenthal has made an important, sensitive, and thoughtful contribution to this demythologizing project. In *At the Heart of the Bomb*, she explores the moral worlds of scientists and engineers working at the Los Alamos and Sandia National Laboratories. Los Alamos is one of two laboratories in the country charged with developing the guts or "physics packages" of nuclear weapons, and Sandia designs peripheral components and the final "delivery packages"—bombs, missiles, and torpedoes. This is an enterprise fraught with moral consequence, but Rosenthal's respondents appear as neither tragic heroes nor sci-fi villains. Rather, they are working people; like most of the rest of us, they are preoccupied with everyday concerns and show regrettably little capacity for moral insight and reflection.

This book has many strengths. Rosenthal, a political scientist, reports on over 260 hours of interviews, conducted in 1984–85, with 85 people who were currently or formerly employed by one of the two laboratories. This sample captures important variation in age, ethnicity, prestige, work history, and moral and political attitudes. She supplements her interviews with sensitive and detailed contextual observations on the history of the laboratories and of U.S. nuclear weapons policy, the culture of the wider Los Alamos community, and even the stunning—and, significantly, isolated—physical setting. Her central research question is, How do scientists justify their work on weapons that can potentially destroy the world?

If we expect our scientists to offer us profound answers to hard questions, we are disappointed by what Rosenthal reports. What we find instead is a closed moral universe—a company town—where issues of scientific responsibility are defined institutionally, hence rarely confronted by individuals. The scientists and engineers interviewed report almost never discussing the morality of their work with colleagues. When asked, they offer a range of responses: some claim to be fighting communism, and others attempt to minimize the proportion of their work spent on weapons. A few express a nerd-macho fascination with the unique technology at their disposal, from fast computers to nuclear shots; others frankly mention the lack of secure job opportunities in science. Several draw self-serving distinctions between nuclear research and research on chemical or biological weapons. Most, with some justification, attempt to spread the responsibility—to American politicians, to the public, and in one case to the man who delivers the mail to the laboratory gate. Rosenthal is evenhanded, treating laboratory critics as austerely as boosters. Her style is more ironic than polemical: she lets her interviewees speak for themselves, reporting details of personal style and setting in a deadpan way. And, as in any real-life conversation, what is unsaid is as important as what is said. Rosenthal's respondents become human in part through their contradictions, stutters, non sequiturs, and resonant ellipses.

This book is also disappointing in ways, especially to the social scientist's eye, because these data are almost entirely unanalyzed. By so reverently individuating her respondents, Rosenthal limits our ability to understand science—at least the weapons lab version—as an institution. The truly scary thing about these enterprises is not the moral failings of individual scientists but the tendency of the laboratories to cultivate technical innovations that will in turn generate new and more dangerous weapons programs. The incentive structure that produces these outcomes is a collective product, and one not unique to weapons labs. A more incisive and generalizable analysis would explore the effects of organizational and institutional dynamics on scientists' views of their work. Perhaps the most important, but least analyzed, theme in the book is the weapons scientists' frequently reported sense of stigma and alienation from mainstream academic science. Within the laboratories that alienation seems transformed into a sectarian ideology, but one that is interpreted differently by different groups of workers. There are hints in the text, for example, that older researchers use Cold War rhetoric to justify their research more often than their younger colleagues. Minority respondents seem to offer more pragmatic accounts than the overwhelming mass of white males. One wonders also whether accounts vary by professional status—do physicists and chemists talk differently from engineers, or Ph.D.'s from technical support staff?

Many academic scientists view applied laboratories, and weapons labs in particular, as parasites. And though it was clearly not her intent, Rosenthal's individualistic analysis allows us to infer that these weapons workers are a self-selected group of moral midgets. I suspect that both conclusions, though comforting in a way, are wrong. A more careful analysis of these interviews would have forced us to think about scientific morality as a product of organizational culture, and ultimately of the relationship between the state and the scientific profession as a whole.

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Cells into Organisms

Morphogenesis. The Cellular and Molecular Processes of Developmental Anatomy. JONATHAN BARD. Cambridge University Press, New York, 1990. xii, 303 pp., illus. $54.50. Developmental and Cell Biology Series.

This book is an excellent critical review of our current knowledge of the physical mechanisms by which organs and tissues are constructed during embryonic development. Bard carefully considers what we know (as well as what we don't know) concerning virtually the full range of morphogenetic events, from gastrulation to the formation of the cornea. Although he does presuppose some prior knowledge of embryology, the descriptions are unusually clear and should be sufficient to lead any interested reader quickly to the forefront of research on dozens of different topics. In

some cases, it must be admitted, this journey to the boundaries of current understanding is not really such a long trip.

At the outset, Bard deals convincingly with the view, all too widely held these days, that what is most needed for the solution of developmental problems is simply the accumulation of more and more data, preferably molecular data. Is it possible, perhaps, that those whose research concentrates on molecular self-assembly phenomena, where subunits associate spontaneously to form larger structures, thereby come to expect that the facts themselves, once accumulated in sufficient quantity, will likewise assemble together spontaneously to form general principles—all without human intervention or the proposal of alternative hypotheses—and that to wait patiently for this to happen is a form of objectivity? Bard is certainly not a victim of any such fallacy. He proves by example how much more useful it can be to gather together facts already known (often from fields so disparate as not otherwise to be known by the same subsets of biologists), to analyze carefully what these facts mean and how they support or contradict alternative hypotheses, and then to consider which further facts would be most decisive.

The specific subjects cover a wide range: they include the formation of kidney tubules, the eversion of imaginal discs in fly metamorphosis, alternative means by which cells can rearrange themselves into hollow tubes, the spreading of epithelia, the rolling up of the neural tube, cell adhesion molecules, tendon and muscle formation, the different types of collagen, the alignment of fibroblasts, and the topological rules obeyed by arrays of aligned fibroblasts, to name just a few. Indeed, very few topics come to mind that deserved inclusion but were left out. One is histotypic cell sorting, which Bard deliberately skips past by saying that the topic was well enough reviewed in the 1984 edition of Trinkaus's book *Cells into Organs* (Prentice-Hall). Nevertheless, this old and contentious topic (what makes cells rearrange by differentiated cell type?) could surely profit from a little of Bard's style of dispassionate dissection. Incidentally, this book overlaps surprisingly little either with Trinkaus's book or with Lackie's *Cell Movement and Behavior* (Allen and Unwin, 1986) and makes an excellent complement to both.

Bard's usual approach is that of "case studies." For each new phenomenon, he reviews the relevant literature and describes alternative hypotheses. He then weighs the evidence carefully and thoughtfully. He reaches his conclusions with sufficient fairness that, even though I disagreed with many of them, I always felt that my understanding of the alternative points of view had been improved. He does not hesitate to point out where the evidence does not seem conclusive. In fact, his several lists of what we do not yet know are among the best features of this book. He even has a special appendix on this subject containing three dozen well-chosen questions. Whether or not these will ever rival David Hilbert's famous mathematical list, they do help to unify the book around what needs to be done in the future.

In the search for solutions to these problems many different kinds of techniques are considered. These range from electron microscopy to studies of force exertion. Nor is molecular information omitted where it is relevant; for example Bard considers the effects on mouse development of deletion of the gene for type I collagen.

Among the techniques mentioned is computer simulation. Alas, Bard touches only lightly on this topic, and states his opinion that "if computing is required, it is not for the amateur." If he means by this that biologists themselves cannot reasonably hope to write useful programs, then I would strongly disagree; and for a conclusive disproof, I would point to Bard's own important work on the simulation of zebra and other striping patterns or to the general workability of Turing's reaction-diffusion system. Those familiar with that aspect of Bard's research will be disappointed to find that he has totally omitted it from his book.

The well-chosen bibliography lists no fewer than 544 articles and books, with citations continuing up through 1989. In addition to a satisfactory index of the ordinary kind, an innovative half-page index of "morphogenetic systems"—for example, disc eversion *(Drosophila)* and epiboly *(Xenopus)*—is included.

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Statistics in Genetics

Genetic Data Analysis. Methods for Discrete Population Genetic Data. BRUCE S. WEIR. Sinauer, Sunderland, MA, 1990. xiv, 377 pp., illus. $48; paper, $27.

As the author accurately states in the preface, this is "a guide to methods of traditional analyses of Hardy-Weinberg and linkage disequilibrium and to the methods for characterizing population structure and estimating genetic distance." When dealing with these traditional analyses, it is indeed a clear, carefully written, and thorough guide to the most rigorous and powerful methods for the analysis of genetic variation. More than that, it is an excellent book for teaching the fundamentals of statistical analysis, even if one is not interested in genetic data *per se*. The author provides a clear, concise review of genetic terminology and experimental methods that makes the book accessible to any biologist or statistician. Also provided are complete descriptions of the models upon which the statistics are based that make it clear what the assumptions and limitations of the methods are. It should be noted that evolutionary models, which might account for the genetic variation observed in today's populations, are not discussed in any detail, and methods of testing evolutionary models or estimating parameters of these models are not described.

Weir explains indicator variables, maximum likelihood methods, moment estimators, and the jackknife and the bootstrap, among other statistical ideas. His forte is calculating variances and testing null hypotheses, and it shows in his clear, careful treatment of the methods. The methods are illustrated with a variety of real data sets, from Mendel's data on peas to the base composition of bacteriophage and mitochondria.

In addition to the traditional analyses, Weir wishes "to review some of the statistical techniques appropriate for restriction fragment length polymorphisms and DNA sequences." These topics occupy about 25 percent of the text. In this rapidly developing area, it is perhaps inevitable that the treatment is not as thorough or definitive. Some recent developments are not treated, and important references are left out. For example, the methods of Engels and Nei for estimating nucleotide variation with restriction site data are not even mentioned. There is no discussion of the analyses of codon usage. Also, in the 30-page review of tree-building methods, covering parsimony, distance matrix, and maximum likelihood methods, there is no mention of phylogenetic invariants (evolutionary parsimony) or neighbor-joining methods. These omissions can be forgiven, given the limited space devoted to modern molecular data and phylogenetic reconstruction. What Weir has chosen to cover is described in his typical careful manner. Besides, most of the methods of the first three-quarters of the book apply equally well to restriction site and nucleotide sequence data.

Weir has produced an excellent book about traditional genetic analyses. I hope he writes a sequel soon, expanding the final two chapters into a full-length book.

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