PREFACE

Perhaps this is the time to reveal how I became a critic of science instead of a researcher. Working on an experiment one afternoon as a graduate student, I noticed that everyone had left the lab. I discovered them in a room at the far end of the building. When I asked why they were there, they explained that the procedure I was following could lead to producing the explosive TNT by a side-reaction, so they thought it safest to evacuate. This lack of confidence in my practical prowess gave me some pause for thought.

Unlike the humanities, science has never had a tradition of divorcing criticism from research. The assumption is that scientists do research; indeed, there is a view that this is the *only* legitimate role for a scientist. When I became Editor of *Nature New Biology* in 1971, *Nature* was one of the very few scientific journals in the world where decisions on publication were taken by full-time editors. The Editor of almost every other scientific journal was a researcher in the field; editing a journal was a part-time activity. It was not surprising, therefore, that when I started *Cell* in 1974, I encountered some skepticism.

Aside from the issue of practical prowess, my problem in following a career in research was that it seemed so narrow. You got to know absolutely everything about one aspect of science, but often at the price of being unable to see the broad picture. The increasing specialization of science since then has only exacerbated the problem. I wanted to understand broad swathes of science.

Modern society has been shaped by tremendous advances in science and technology. These hold enormous promise, but also dangers: to assess this rationally requires some understanding of what constitutes science and its limitations. During the COVID pandemic, there were frequent cries of "follow the science," but failure to understand the assumptions underlying the science, and therefore its limitations, may have been responsible for some of the difficulties in dealing with the pandemic.

The value system of science is nonpareil: self-contained and self-validating. In this book, I want to explain how science works. This is not an idealized view; it is science, warts and all. I try to show not only how science should, and often does, work, but also how failings in the system can misdirect it.

This sounds as though I want to dispel the mystique of science. Well, yes and no. I believe fervently in the distinctive, in fact the unique, value system of science. But it does have its flaws. Some are imposed by the institutional framework within which it functions—especially the means of communication (publishing results as research articles), and funding (the need to apply for grants on a continuing basis). Some are due to failings on the part of its practitioners (especially excessive conformance to conventional wisdom). I believe in any case that science benefits from being seen clear-eyed.

The history and philosophy of science take what you might call a "classical" view: that science is practiced by individuals who obtain data to test hypotheses. The main questions I want to ask are how far this description was true, and how has the basis of the scientific endeavor changed in this century.

The trend today marks a move away from individual investigation. "Big science" uses massive amounts of data to replace individual experiments, and entails a different way of thinking about science. A move to use AI (artificial intelligence) techniques to analyze data even raises the question of how long science will continue to be driven by human intellect.

The effects of these changes outside science have scarcely been noticed. Science is regarded as something of a black box: so long as it delivers the goods—whether in the form of better medicine or technological spin-offs that improve daily life—society is prepared to pay the bill without too much concern as to just how those results are achieved. Yet if there is to be informed consent to the progress of science, it is necessary to understand its nature, and the implications of the way it is changing. The human impact of science to date is undeniable, but we have to think about how that may be enhanced by the changes in science itself.

I was concerned when I started to write this book that science might be losing its way. Were scientists being replaced by technicians? Now I believe the situation is not so drastic, although certainly things have changed. My purpose here is to consider the consequences of that change. The main concern is not so much with how information is obtained, but with the capacity to make intelligent use of it.

I start with the major change in science of the past two or three decades: the move from small-scale research in groups of no more than a few people, led by one principal investigator, to a larger scale requiring many researchers, directed in a top-down manner, sometimes by a committee rather than an individual. What does this mean for the very nature of science as well as for the activities of the participants? Has science—in particular biology—changed from testing hypotheses to trawling for data?

Then I look at the medical and industrial implications of molecular biology, before turning to how scientists communicate, how research is funded, and how science is impacted by politics and ethics. All through this, I try to show how the value system of science leads to validation of scientific results, what its limitations may be, and how research reports should be assessed.

I take my illustrations of the traditional scientific process from what many regard as the golden age of molecular biology, a unique period in biological science, because the discoveries were so fundamental and continuous, creating an unparalleled intellectual furor. I suppose it lasted from around 1960 for more than a quarter century. I draw on this period because the sheer pace of discoveries magnifies the sense of what science is about, how it works, and (sometimes) how it doesn't work.

The principle would be the same whether you consider a century of chemistry or physics as opposed to a quarter century of molecular biology, but the focus is sharper. Comparing the history of this period with the subsequent quarter century allows us to ask what we have lost or gained by the change in the way science has been conducted since the golden age.

For a view of what leads to (or impedes) great discoveries, I follow the history of changing views of the gene and DNA, from Mendel, through Watson and Crick, to the present day. Later I look at epigenetics, which gives alternative views of the working of heredity. The rise and fall of dogmas illustrate the role of fashion in science, with the jury still out on epigenetics. Finally it is time to consider the aspects of biological science that most directly impact human life: the sequencing of the human genome and the development of gene editing and its potential.

I draw on my experience at *Cell* to explain how science really works. *Cell* became an important journal during the golden age, publishing many of the most significant papers in biology. The submission, review, and reaction to those papers, especially from behind the scenes, reveals a good deal about the conduct of science. I look at how the trends from that period have accelerated into the present. I want to explain what happens when you "follow the data," and why sometimes the structure of science prevents that from happening.

After years immersed in science, I spent a period (not as long) immersed in something else—the world of wine, as a matter of fact. With the objectivity of greater distance, some of my implicit assumptions have become clearer, and I have changed my views on some issues of scientific conduct. The question today is whether and how science can continue to deliver the goods, both as intellectual stimulus for its participants, and in the form of benefits for the population.

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