Discovering, Inventing and Solving Problems at the Frontiers of Scientific Knowledge *by Robert Scott Root-Bernstein.*
(Harvard University Press, Cambridge MA and London, 1989), pp. xiv + 501, $US35.00, ISBN 0-674-21175-8.

Root-Bernstein is Professor of Natural Science and Physiology at Michigan State University. He is perhaps the most prolific writer on the process of scientific inventiveness: not the inventiveness behind inventions, but the inventiveness of intellect behind scientific discoveries.

Had he spent the ten years it took him to write this book on the former task, he would undoubtedly be the most prolific writer in this field. But instead he wrote this treatment of how scientific discovery might be fostered, based upon the diaries and journals, and reports of friends of the learned discoveries of our era. Scientific discovery might be fostered by freeing up our prospective discoverers.

> Up until about World War II, most scientists had some financial independence. Lavoisier, Darwin, J. Willard Gibbs, Hans Driesch and his collaborator Curt Herbst, J.A. Le Bel, Rayleigh, the Haldanes, and many others were wealthy "amateurs". Norman Pirie believes that at least seven out of every ten of the men who worked with him at Cambridge had some inherited money, which "gave them a feeling of security and independence." Others, including J.J. Thompson, Almoth Wright, Arrhenius, and virtually every major biochemist during the first fifty years of this century, benefitted from longterm no-strings-attached fellowships such as the Grocer's Fellowships, Trinity Fellowships, and Rockefeller Foundation Fellowships.
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> 'Richard Goldschmidt described a researcher's heaven at one of the Berlin Kaiser Wilhelm Institutes, where he had "the best laboratory in the world with unlimited space, technical help, assistance, multilingual secretaries, the best instruments and equipment, and complete freedom to use all this without bureaucratic interference, without requisition slips or purchasing departments, my time was completely my own, and I was even free to move anywhere and take my funds and salary with me if I thought my research required it." Then he moved to Berkeley, and found out how the American bureaucrats watched every penny, monitored every requisition, and confiscated every unspent cent.

These quotations represent less than a third of page 395; some pages have upwards of 50 scientists, with, and as often, without their discoveries.

The question, of course, is how good a discovery scientist was Goldschmidt — or Lavoisier, or Darwin or the Haldness, or J.J. Thompson — for it is from this that Root-Bernstein contemplates his mode of recovering the characteristics needed to support an era of scientific discovery.

The book requires an easy knowledge of scientific discovery or, for those of us less easy with the topic, that we simply follow our various guides, who fill in those details which are necessary to Root-Bernstein's tale (and leave the rest to the notes, which are excellent). The guides, as I call them, are not familiars of our course through the history of science. These are there, too: Benjamin Franklin, replying to a critic of one of his ideas, around the time he was discovering atmospheric electricity: "What good is it?" the man asked. "What good is a baby?", Franklin reponded. Macfarlane Burnet is here, with some advice: "Do as large a proportion as possible of your experiments with your own hands." And Gus Nossal, who once commented that every new theory is sufficiently fuzzy to allow an intelligent person to pick any number of holes in it, but that such critical actions are detrimental to progress. (pp.304,418).

But the guides are not these familiars, living or dead. The guides are a half dozen fictional characters who have undertaken, for six days, to explore the notes, biographies, scientific writings and journals of thousands of the discoverers of science, from the beginnings of recorded time to the present. The first chapter is called Preparations: Toward a Science of Science. Its hope is that "by careful analysis of past discovery, we shall find a way of separating the effects of good organisation from those of pure luck"(p.1)

In this chapter, Jenny, begins the notebook she will keep throughout the six days: 'Imp's friend hunter Smithson came to dinner tonight. What a tonic for Imp! And what a surprise for me. Imp always insisted Hunter was not your usual chemist, but his knowledge of history quite took me by surprise.'(p.9) Jenny is an historian, and not altogether restricted to the history of science. Her relationship with Hunter develops over the six days until, 279 pages later, in one of the Transcripts which are found throughout the book, she solves one of the classical problems in electrical conductivity, which Hunter has posed from the dissertation of Arrhenius in Sweden in the 1880s:

> **Jenny:** I know! The solvent! just like last week with van't Hoff.
> **Hunter:** Why are you an historian? I've had dozens of students with less natural aptitude than you.
> **Jenny:** But hopefully more interest. Besides, what makes you think I don't need the same aptitudes to be an historian?
> **Hunter:** Sorry my scientific chauvinism is showing.

And so it goes. A story about six people trying to work out from discoveries of the past how to foment them now. And not without passion for the loss of discovery; or, more aptly, the loss of the wherewithal for discovery.

> Consider what would happen to a Darwin or an Einstein today. Could Darwin carry out his twenty-year program to restrucure biology within the present academic system? If he were a wealthy amateur, would anyone listen? Would a patent office even put up with such an employee? (p.404).

And as we might expect, Einstein's failure to get into school gets a mention.

But here is the difference with Root-Bernstein's book: Einstein's failure in school is usually mentioned as a polemic, as rhetoric. Here it is mentioned by the character Ariana, as part of her contribution to the colloquium, the exploration of the artistic temperament of scientists who make discoveries:

> After failing the entrance examination to the Zurich Polytechnique Institute at the age of fifteen, Einstein matriculated at the Kanton Schule at Aarau, Switzerland. The Kanton Schule was founded in 1802 to embody Pestalozzi's principles of teaching students the "ABCs of visual understanding" ahead of and in preference to visual and mathematical thinking. It was the turning point in Einstein's education. In that year the largely nonverbal and highly visual Einstein invented his *Gedankenexperiment* and encountered teachers who could appreciate and develop his visual-kinesthetic style of thinking. (p.331).

Ariana goes on to offer a list of 400-odd Nobel laureates, and their forbears, over the last two centuries who were visually or musically or otherwise artistic- and a short list of 13 "nonartistic eminent scientists" over the same period.

At times we wish he had published this in three books, spread perhaps over the ten years (five of which was spent researching and writing on a prestigious Macarthur Prize Fellowship), such is the scholarship of Root-Bernstein's work. Much of it is prosopographical (which Jenny tells us is the "biographical study of a group of people aimed at determining similarities and differences" (p.232). It explores, as does Ariana's list of artistic scientists, what Root-Bernstein suggests we call "synscientia-knowing in different ways at once" (with reference to Douglas Hofstadter and others who have explored the logical relations between

math and music, and a nod to such cross-sense experiences as synesthesia, where we can 'taste' a colour).

Which brings us to paradigms, and such. Kuhn, and others are here. But they don't hold the floor. Paradigms far, far back in scientific history are shown, exposed, and discussed. Interestingly, in my field of anthropology, albeit cultural anthropology with a cybernetic bent, Leslie White is here, but not Gregory Bateson, perhaps the bravest of us. (Interesting, too, for it was Bateson who organised the Wenner-Gren Conference on the Effects of Conscious Purpose on Human Adaptation, where six real scientific discoverers met for six days in 1968 to try to figure out from widely variant data that great question; recorded in prose and journal and transcript by Mary Catherine Bateson as *Our Own Metaphor,* Alfred Knopf, New York).

Yet Richard Feynman is here, so we are not left without the brave by any means. The late Richard Feynman, Nobel laureate, was the man who dared to tell NASA that the workers on the Space Shuttle had been trying to warn their managers of the possibility of a crash. Perhaps the only glaring exception is Charles Sanders Peirce, whose might have attended almost as a participant, so little known is he even in his native United States. Yet he is the one who gave us American Pragmatism, and sired, intellectually, Dewey and George Herbert Mead, and many of the Chicago School; as well as his own invention of abduction, a third form of reasoning, apart from deduction and induction, in which the data fall into place as the theory which explains them comes to mind.

Each of us would have those favourites, or mentors, whom we would like to see not missed out. This would surely be the only exception we might possibly take to Root-Bernstein's work — and even then feel possibly a little churlish in the face of such generous scholarship. This honesty, and generousness of intellectual spirit, is what commends the book to us all. It can be dipped into or read in huge chunks. It should be on any shelf which has Peter Medawar, or Poincaré; its dialogues would sit nicely next to the dialogues of Popper and Eccles (Karl Popper and John Eccles, *The Self and its Brain,* Springer International, 1977). As an annotated reference book, it is an *enormous* resource; as an adventure book, it is a pleasure to read. And it has such fine *spirit.*

The character Imp, whom we are sure is the author's *alter ego* or at least that portion of his *alter ego* fashioned after such irresistibly forthright and honest scientists as Richard Feynman — says in his last report to the six,

> For the complacent, for those who are satisfied with their present position in science, and for those whose fondest desire is to become the editor of several journals, to sit on all the relevant NSF committees, to become head of the department at thirty-five and president of the university at fifty — -in short, to do the things that Pasteurs, Mendels, Darwins, McLintocks, Curies, Maxwells, Einsteins, Feynmans never do — the body of my report is not for you.

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Melbourne

The Boundaries of Economics *by Gordon C. Winston and Richard F. Teichgraeber III*
(Murphy Institute Studies in the Political Economy, Cambridge University Press, Cambridge, 1988), pp. xi + 117, £75.00, ISBN 0-521-34450-6.

The title of this slim volume is somewhat misleading. None of the five essays is really concerned with the boundaries of economics. Rather the common