Boltzmann's best known contributions to physics lie in the realm of the kinetic theory of gases and in statistical thermodynamics, which occupied him for forty years. He extended the work of Maxwell and others, generalizing the analysis of the distribution of energy among atoms and molecules. Using similar methods he also generalized the analysis of transport

Ludwig Boltzmann, as drawn by his student Karl Przibran, later Professor of Experimental Physics at Vienna University.

phenomena in non-equilibrium systems, arriving at the famous Boltzmann transport equation. His greatest achievement lay in the discovery of a functional law which related thermodynamic entropy to the statistical distribution of an ensemble of molecules. This law, which was written by Planck in the form $S = k \log W$, is inscribed on Boltzmann's tombstone. Boltzmann also extended the mathematical analysis of entropy to non-equilibrium states which are not covered by the thermodynamic definition. His experimental work included the study of dieletrics and of diamagnetism.

In the late nineteenth century many physicists became impatient with the penetration of metaphysical concepts into physics, and with the din of competing theories in electromagnetism and in thermodynamics. There were two distinguishable responses to this predicament, positivism, led by Ernst Mach, and conventionalism, led by Boltzmann. Positivism dismissed hypotheses of all sorts, metaphysical and physical, as harmful, or as mere mnemonics at best and wished to reduce the laws of physics to a summary of observation-statement.

Largely because of the fierce positivist opposition to the atomic theory, Boltzmann was forced to articulate an alternative epistemology of physics, which combined the ancient mathematical device of 'saving the appearances' with a dash of Kantian idealism. According to Boltzmann, hypotheses are indeed useful but not as candidates for physical 'reality', as we have no access to such reality, but rather as convenient pictures which stimulate and guide research and which can be made increasingly self-consistent. In this manner, at one stroke, Boltzmann undermined the pretensions of metaphysics and of theorists, an defended his right to an atomic 'picture'.

Positivism and conventionalism have competed for the minds if not the hearts of physicists ever since. Conventionalism, for example, is behind the reduction of force, momentum and the electromagnetic field intensities to mathematical constructs, and behind the reduction of Newton's laws to definitions.

It is also responsible for the contemporary preference for using the term 'model' rather than 'theory'. There were many other sides to Boltzmann's philosophy, of course. He was an ardent Darwinian, for example.

Broda laments Boltzmann's lapses of literary style. Indeed, Boltzmann's historical errors, confusing Roger Bacon with Francis Bacon, for example; his description of the Greeks as 'naive' and his definition of metaphysics as 'mental migraine' heralded, perhaps, a decay of style in physics. Faraday, Maxwell or Helmholtz would not have committed such solecisms.

Broda's analysis of Boltzmann's science and philosophy does not represent exacting scholarship, and the translation has peculiarities such as "atomistics" and the "obligate increase in entrophy". The non-specialist, however, will find this a good and informative read. □

John J. Roche teaches History of Science at Linacre College, Oxford.

Intelligent steps

Simon Lavington

Towards Fifth-Generation Computers.
By G.L. Simons.
National Computing Centre: 1983.
Pp.225. £10.50, $18.10.

The Fifth Generation:
Artificial Intelligence and Japan's Computer Challenge to the World.
By Edward A. Feigenbaum and Pamela McCorduck.
Addison Wesley/Michael Joseph: 1983.
Pp.288. $15.55, £9.95.

FEW TOPICS in computing excite so much emotion as Artificial Intelligence. Since anyone possessing a brain — artificial or not — is entitled to join the debate, the task of disentangling fantasy from reality is not easy. The dream of artificial intelligence has been with us from the early days of computers, with several respected pioneers expressing the cautious hope that machines would one day exhibit intelligent behaviour. The reality has yet to appear.

Artificial intelligence research concentrated for many years on identifying and reproducing basic mechanisms of learning and problem-solving: laudable aims, but difficult to achieve with the primitive computing tools available and the fragmented nature of the research effort. General theories were slow to evolve, and the few demonstrations of problem-solving to emerge from computer science laboratories hardly seemed relevant to real-life applications.

A shift of emphasis took place in the 1970s, when some of the general techniques of reasoning, notably inference mechanisms, were applied to collections of specific knowledge. The aim was to make the computer appear as an expert assistant. Predigested knowledge, in the form of rules and facts about, say, respiratory diseases, was embedded in a friendly question-answering framework and the so-called Expert System was born. Here at last was a money-making product which hard-nosed industrialists could appreciate. More importantly, there arose the conviction amongst a small but growing band of computer users that information systems could be made 'smart': that dumb database systems could one day be replaced by intelligent knowledge-based systems.

This vision of intelligent knowledge-based systems has not only become the acceptable face of artificial intelligence; it is seen by many as the essential ingredient of future computers. Nowhere is this more firmly believed than in Japan. The Japanese, casting around in 1979 for a policy for long-term economic survival, launched an investigation into the most likely trends for the next generation of computers. The resulting report described their image of the 'fifth generation' computer, and stressed the importance of three functions: problem-solving and inference-making, knowledge-base management, and intelligent interfaces. Soon the 'fifth generation' had become a peg on which anyone felt free to hang opinions and prejudices, hopes and fears, about every aspect of future computer hardware and software.

Although many strands of research were naturally assumed to contribute to the fifth generation, Japan's uncompromising inclusion of artificial intelligence provoked the most comment. The debate then moved smartly out of academia when the huge scale of Japanese investment in fifth generation research became apparent. In the UK, the Alvey Report and its recommended £350 million for information technology research is a direct response to the perceived Japanese challenge. Likewise, the books by Feigenbaum and McCorduck and by Simons take

their cue from Japan.

Geoff Simons' informative book is a helping hand for those perplexed by the thought of a fifth generation. He leads the reader so smoothly through the jargon that, although one does not emerge technically-speaking much the wiser, it does not seem to matter. This is no confidence trick — merely the effect of being led by an enthusiast who encourages long views. There is, in any case, a rich bibliography for the diligent. Whilst artificial intelligence and expert systems get a suitably prominent treatment, the book also covers the other likely components of future computer systems. Thus there is discussion of trends in integrated circuit technology, the rationale behind novel computer architectures such as dataflow, the use of programming languages such as PROLOG, and the possibilities opened up for man-machine communication by voice recognition and by visual perception. With Geoff Simons of the National Computing Centre as companion, one can enter the fifth generation debate and appear as intelligent as the next person.

The subtitle of the *The Fifth Generation* stamps it as a political statement. Professor Feigenbaum is one of California's Grand Old Men of artificial intelligence and Pamela McCorduck has long been an enthusiastic promoter of the cause. Their thesis, advanced with a touch of chauvinism, is that America invented the bulk of artificial intelligence technology and is now about to be overtaken as leader of the field. It is thus a plea for the US to spend more money on artificial intelligence research. To the computer scientist, this is a familiar cry which provokes adulation or derision, according to belief. To the innocent bystander, the arguments provide rare glimpses of a scientific sub-culture engaged in internecine strife.

Do not, therefore, read Feigenbaum and McCorduck to learn about fifth generation technology. Rather, read them for their perception of the evolving role of information processing in society, and their belief in the ultimate ascendency of intelligent machines. If the background to their canvas is the whole of recorded history, the foreground is firmly occupied by what they state to be "the American predominance in everything from computing to finance, from industrial output to quality of life". This predominance is seen by Feigenbaum and McCorduck to be under attack from an unexpected source — Japan — and the message is that America ought to be worried. To a European audience, used to losing empires, the book's cries of righteous alarm could be mildly amusing if they did not at the same time contain a warning for all countries who aim to survive as industrial nations. The race to the fifth generation is on, and winner takes all. □

Simon Lavington is a Senior Lecturer in Computer Science at the University of Manchester.

Foibles programmed

Margaret Boden

In-Depth Understanding: A Computer Model of Integrated Processing for Narrative Comprehension.
By Michael G. Dyer.
MIT Press: 1983. Pp.458. $40.50, £31.50.

IF there is one prospect more alarming than having one's phone tapped by Boris, it is having one's diary read by BORIS. Denis Thatcher's resident Russian spy is a mere mortal, so may have a certain grudging sympathy for the sins that flesh is heir to. But BORIS's discretion in such matters cannot be counted on, for BORIS is a computer program. The potential threat to one's privacy arises because BORIS is a language-using program designed to understand narratives dealing with human plans, motivations, and emotions.

BORIS's data-base and inferential strategies represent some of our everyday knowledge about such matters as adultery and divorce, and the emotional (and legal) tangles that they may involve. Given the sentence "Paul wanted the divorce, but he didn't want to see Mary walk off with everything he had", this enables it to interpret "walk off with" as meaning possession rather than perambulation, and to see Paul's distaste for this prospect as a natural reaction to his discovery of his wife's infidelity.

Its representation of interpersonal phenomena such as anger, jealousy, and gratitude can lead it to see the point of an incident, without this having to be explicitly stated. For instance, it guesses the topic of a telephone call (Paul is asking his lawyer-friend Robert for advice) as it knows that present help may properly be requested and willingly granted because of a past favour.

The program also has some general knowledge of planning and of stereotyped behaviour: such as that clothes are usually kept in bedrooms, that to get to one's house from a restaurant one may need to be driven there, and that having the waitress spill soup on one's clothes may lead one to refuse to pay for the meal. All this heterogeneous knowledge is integrated in BORIS's processing (including its parsing) to enable it to give sensible answers to questions about a story in which a careless waitress leads to the discovery — with a witness — of a wife *in flagrante delicto.*

BORIS is the most impressive system based on the Schankian approach to natural language processing, for it integrates many different sources of knowledge in complex ways. A relatively novel concept is the "thematic abstraction unit", (TAU). TAU's are highly abstract schemata whose function is to organize memory and direct the process of understanding. They also support analogical reasoning and enable one story to remind