Preface
to: James Franklin
What Science Knows: And How It Knows It
(Encounter Books, 2009)

Any time is a good time to contemplate the advances of science. But the ideal occasion is a visit to the dentist. Not only is the distraction welcome, but the intrusion of drill or laser into the mouth cavity – so close to where one feels one's real self is located – prompts reflection on how much worse things could be. Or how much worse they actually were, before science worked its magic.

Take the case of Charles Whitworth (1752-1825). The state of Earl Whitworth's teeth as of 1825 is known exactly because he was buried in a triple-shelled lead coffin, excavated in the 1990s. He had been British ambassador to Napoleon and Lord Lieutenant of Ireland and was able to afford the highest standard of dental care his age could provide. That care, unfortunately, included the provision of tooth powders and tinctures of the sort advertised to "eradicate the scurvy and tartar from the gums; make the teeth, however yellow, beautifully white…" The reason that the teeth came up beautifully white was that the products contained abrasive materials made of shells, corals and ground pebbles, with tartaric acid. Whitworth's teeth show the effects. On the front of the right upper incisors, where a right-handed man would naturally brush hardest, the enamel is completely missing. Having exposed dentine is a very painful condition, especially when trying to eat or drink anything cold or hot.[1]

A normal citizen of any functioning country today is the beneficiary of dental knowledge that Whitworth would have given his eye teeth for, what was left of them. We accept the benefits, and if we choose we can understand the science behind how they work.

Victims of land mines and napalm, it is true, are entitled to their vote that science sometimes has serious ill effects, and it is possible that a biology laboratory will yet come up with a microorganism that eats us all. It is the nature of science that it

[1] M. Cox, J. Chandler, A. Boyle, P. Kneller and R. Haslam, Eighteenth and nineteenth century dental restoration, treatment and consequences in a British nobleman, *British Dental Journal* 9 (2000), 593-596; effects described in M. Addy, Dentine hypersensitivity: new perspectives on an old problem, *International Dental Journal* 52 (2002), 367-375.

delivers power without responsibility. It delivers power because it delivers knowledge.

But scientific knowledge has many enemies. They resent not just the uses of science, but its aims, methods and discoveries. The internet and World Wide Web (provided by science, of course) are flooded with complaints and suspicion about it. Scientific theories, it is variously alleged, are socially constructed, determined by vested interests, undetermined by data, dependent on the observer, logically impossible to confirm, always falsified in the long run, Western, godless, linear, patriarchal, reductive and so on – all with the implication that scientific theories are not to be believed.

Science has its defenders too, many of them excellent at such individual tasks as refuting postmodernist attacks and defending particular points in science and the philosophy of science. What they have not done is provide a simple and straightforward introduction to "why science is rational".

This book attempts that task. With a mixture of considerations about the logic of science and illustrations from real science, it explains from the ground up how science has established conclusions that are worthy of belief – absolutely certain conclusions in the case of the mathematical sciences, very highly probable ones in empirical science.

The core of the defense of scientific rationality lies in the objectivity of logical relations. That applies both to the deductive relations of mathematics and the probabilistic or non-deductive ones of empirical science. The reason we can prove and hence believe with certainty that the square of any even number is even is that deductive relations exist between truths about numbers and those about their squares. The reason we can rely on what the dentist tells us about our fate over the next hour – though with less than 100% certainty – is that there are logical relations holding between evidence and hypothesis. The evidence lies in the clinical trials that the dentist's materials and equipment have undergone, and the results of those trials bear on our case for logical reasons.

We begin, then, by explaining how an objective view of the relation of evidence to conclusion solves the classical problem of induction, which asks how we can know (with high probability) that all ravens are black when we have observed only finitely many black ravens and it is logically possible that the next raven should be white. If that problem cannot be solved, there is not much hope for defending the rationality of the more esoteric reaches of science.

Basic though it is, the rationality of induction is sufficient for defending science against the broad-brush irrationalist attacks on it from twentieth-century philosophy of science and from later sociologists of science and postmodernists. An excursus on their objections reveals their logical mistakes and gross misunderstandings about the logic of evidence and conclusion.

We then survey some typical examples of knowledge in the natural, cognitive and social sciences, to give some sense of the variety in the methods used in real science. There is more than usual attention paid to the mathematical sciences, not only because they long ago found the gold standard of knowledge, mathematical proof, but also because the computer revolution has extended the reach of mathematical methods through most of science.

After a brief glance at how science as actually realised in people and institutions supports the discovery of scientific truths (or occasionally does not), we conclude with a view of the limits of science. Some are imposed by the problems of observing the very big, very small and very old, and understanding the very complex. In particular, the controversies about evolution and global warming arise from the inherent difficulty of understanding the complex systems involved. But beyond that there are more principled limitations to science, namely the essentially non-scientific character of some of the topics on which we most desire and need knowledge: consciousness and ethics.

Science has taught us not only what to think but how to think. Let us learn how it did it.