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KAMPOURAKIS, K. and MCCAIN, K. (2020). *Uncertainty. How it Makes Science Advance*. New York: Oxford University Press.

Communicating philosophy to broad audiences is not always an easy task. Kostas Kampourakis and Kevin McCain's *Uncertainty—How it Makes Science Advance* (Oxford University Press, 2020) has the merit of taking a complex philosophical topic—i.e., how scientific practice and knowledge relate to epistemic and psychological uncertainty—and make it accessible to the general public. It also has the virtue of reminding us philosophers of science that our abstract discussions, when contextualized and approached in the right way, can be extremely relevant for social concerns. What this book offers to the reader is a clear, illustrative guide for understanding that there's knowledge, understanding, and rationality in science even in the absence of certainty—and, to an extent, *precisely because of it*.

The book is organized into three parts of five chapters each. The first block introduces a series of topics that, overall, set the framework for accepting that certainty is not required for knowledge—either scientific or not—, and that trusting in science is not, and should not be, related to being certain. Psychologically, being certain precludes us from wondering and questioning ourselves, thus leading to dogmatism. Any psychological certainty about how the world is can act as a barrier for inquiring about it and being open to alternative possibilities. Epistemically, it is an unachievable goal, since we can never be secure that it is *impossible* that we are wrong. While we feel a need for our beliefs to be certain, dealing with uncertainty should be a part of our maturation process, and perhaps even of our education systems, as the authors defend (pp. 28-32). A key point for dealing with uncertainty is to discern between those things we know nothing about, and those for which we have grounds to conceive their probability of taking place. When we buy a lottery ticket, it makes a difference to know how many tickets there are in total. Whether we will win or not is uncertain either way, but knowing our odds will allow us to make more rational choices, such as not quitting our job too soon in the expectation of having the lucky ticket. When it comes to science, this understanding of uncertainty translates into a rational confidence in its progress. Despite there being complex biases in scientific methodology—it is a human enterprise after all—, the authors make the case that the self-correcting nature of science makes it the best candidate amongst the possibilities for deserving our trust and helping us deal with uncertainties.

The second part of the book articulates a series of exemplar domains of science where uncertainties are sometimes poorly understood by the general public, leading to

misrepresentations of their actual scope and focus. This comes in two extremes of trust in science: distrust and overconfidence. Distrust is exemplified by climate change (Ch. 6), vaccination (Ch. 7), and human evolution (Ch. 8), all areas in which uncertainties about specific aspects are often overemphasized and taken to imply that the disciplines are entirely untrustworthy. The complexity ingrained in particular elements—such as the prediction of *weather* details rather than general climate trends, or the specifics about when and how much Neanderthals interbred with *Homo Sapiens*—is sometimes mistaken for a lack of consensus about, and evidence for, the bigger picture of these domains. Interestingly, the authors point at the media being an important misleading factor, when in the search of an appearance of neutrality it tends to show different positions about the same topic. As they exemplify it, when people face a debate between a scientist warning of human-caused climate change and a scientist who is skeptical about it, "[t]hey typically are not told that the scientist speaking in favor of the consensus view ... is representative of thousands of other scientists, whereas the dissenting scientist is representative of just a handful" (p. 91).

We have clearly seen this problem in the still ongoing worldwide COVID-19 crisis. Some unavoidable uncertainties about potential negative reactions to vaccination for each particular individual at times have eclipsed in the media the overwhelming quality of knowledge on the efficacy of vaccines for lowering death and hospitalization rates. Setting—obviously relevant—political and economic aspects aside, media attention has often focused on the wrong sources of uncertainties, contributing to an image of chaotic research, similarly to when apparently neutral debates on climate change raise doubts about there being scientific consensus about it. The fact that we might win the lottery if we buy a ticket does not undermine the fact that we all have thousands of times higher odds of not having the winning ticket. Similarly, the fact that we might get a serious reaction to a vaccine does not undermine the fact that we all have thousands of times higher odds of not having it. And the fact that we might still get the disease despite being vaccinated does not undermine the fact that our odds not to have it, and the odds that it will be much milder, are similarly much higher. This is a good example of why Kampourakis and McCain insist that not all uncertainties are the same: knowing about the chances can really make a difference.

On the other hand, overconfidence is illustrated by genetic testing (Ch. 9) and forensic science (Ch. 10). In these areas, people often fail to understand that there are uncertainties inherent to them that ought to make us more cautious when it comes to acting in accordance to particular results obtained from them. For example, a genetic test may be able to detect with some—definitely not perfect—accuracy the presence of a gene that is understood to be statistically correlated with a particular disease in humans. In addition to a lack of knowledge of the precise role of the gene *when the disease is present*, the development of the disease is by no means a necessary consequence of having the gene. Nor is typically the lack of it a guarantee that the disease will not develop. In sum, people taking genetic tests—an activity that is apparently becoming more and more profitable in the last few years—

tend to underestimate the uncertainties intrinsic to our understanding of the role of genes in our health, magnifying how much they will benefit from knowing their so-called "genetic predisposition" to specific diseases.

The final block of chapters argues that, far from being exceptions, the uncertainties that these domains face are an unavoidable part of scientific practice more generally. Social aspects, complexity, and the nonexistence of one unique and definite "scientific method" are universal ingredients of scientific practice. Here is perhaps a point where the book could have benefited from mentioning differences, and not only similarities, in methodologies across sciences. Probably due to the previous expertise of the authors, the examples drawn in the second block all seem a bit too similar. They all point at highly complex natural systems, all biological except for the climate science example. This can cast a doubt on whether the same principles would apply to domains such as fundamental physics—which is the paradigm of so-called 'hard science'—or to social sciences—the paradigm of 'soft science'. While the latter are not even mentioned, physics is alluded to on several occasions, but always through a superficial lense that clashes with the general tone of the book—e.g., the mention of Heisenberg's *uncertainty principle* is a bit misleading. The idea that there are 'hard' and 'soft' sciences, even if totally discarded in academic circles, is a pervasive one in the public. Perhaps being explicit about differences in things such as the level of mathematization of different domains would have been helpful for making the argument of the book even more persuasive.

That concern aside, the last part of the book makes it fairly clear that the idealizations and limitations ingrained in our scientific theories and models render both explanations and predictions uncertain in all the sciences. The latter are nonetheless key components of what can be considered the actual goal of science: understanding. When we understand phenomena, we have knowledge about it that we can use in explanations and predictions about it. Recognizing the uncertainties in this knowledge only fuels the engine that searches for an even deeper understanding. This is how science advances, namely by an awareness of what are our uncertainties and how supported our beliefs really are by evidence. Only this awareness is capable of bringing new ideas that are better in explaining and predicting natural phenomena than those we already accept in the scientific community.

Despite the unquestionable merits in this pedagogical presentation, the book surprisingly makes no mention to pseudoscience, a matter that seems to me to be highly intertwined with its core argument. It is indeed a mirroring problem in the trust in science debate: that misunderstanding uncertainty often leads to accepting pseudoscientific perspectives. This is slightly different from the "all goes" concern the book raises at a point, while it has especially harmful consequences. Believers of pseudoscience are not mere science deniers or skeptics—like the anti-vaccine movement that is having such an enormous impact these days. Neither are they absolute relativists, believing that any belief is as legitimate as any other. Pseudoscience believers often defend the scientificity of their own dogmas, and they tend to do so pointing at the uncertainties of

real science. For example, some seem to believe that homeopathy would reach scientific standards if put to test, but that not enough homeopathy experiments are made because it is a blindspot in our current theories and researchers feel unjustifiably certain about it not being a valid hypothesis whatsoever. Here, the pseudoscience believer advocates for the scientificity of her views by twisting the significance of uncertainty in science.

Another concern this book raises to me is that it is explicitly aimed at non-scientists in the general public, while it should be aimed at scientists as well. In other words, this is a book from two theoreticians of science—a science education expert and a philosopher of science—to *both* scientists and the general public, but probably more stress could have been made on this throughout its pages. Of course, and as the book makes clear, a good scientist should be already aware of the uncertainties inherent to scientific practice. Nonetheless, most of the points made in the book are by no means trivial for the scientific community in general, that would also benefit from learning about them in order to be more self-aware and better communicate its work to the public. Trust in science also depends on the scientific community being transparent about its own uncertainties, thus fully aware of them.

By no means these points undermine the fact that this book translates the debate of important philosophy of science questions into a writing style that very much welcomes a non-specialized reader. The book makes it plain that epistemic certainty is simply not possible, a fact that renders psychological certainty undesirable. But, quite importantly, it also explains clearly how this doesn't mean that we should not be more confident about some things than about others, let alone that knowledge isn't possible. Instead, it advocates that we need to match our psychological certainty to our epistemic one—that is, we need to be *rational*—, accepting that while our scientific knowledge cannot be certain, it provides the best understanding of nature that humankind has come up with to date. As the authors state in the last pages of the book, "recognizing that science is trying to achieve deeper understanding of natural phenomena rather than certainty helps us to appreciate the tremendous success of science" (p. 204).

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