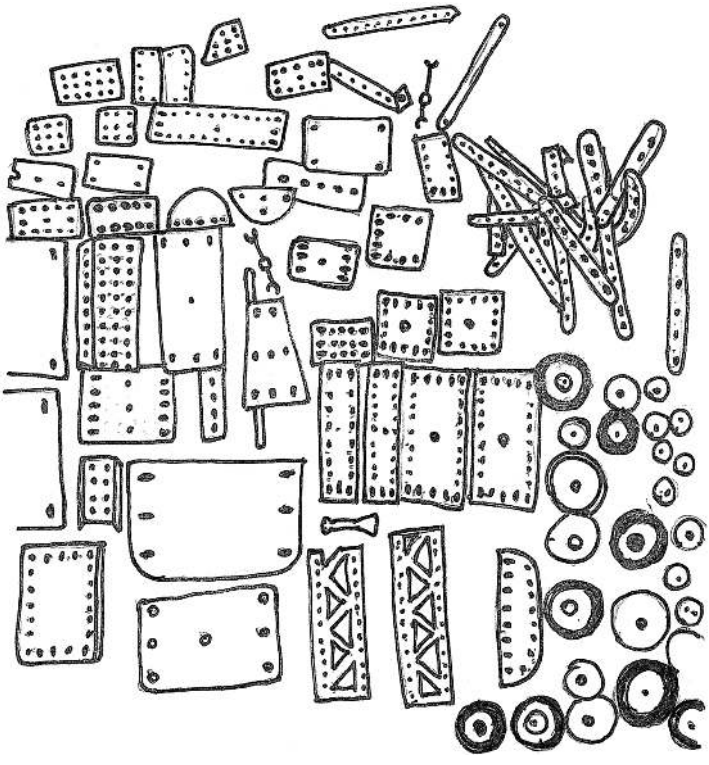

The Meccano set of science
Drawn by Adrian Harris especially for this book. Thanks Adrian!

Introduction

What does a philosopher see when she looks at science? What do you see?

Here are three common images of science, widely shared alike by philosophers, scientists and people in general:

1. Science = theory + experiment.
2. It's all physics really.
3. Science is deterministic: it says that what happens next follows inexorably from what happened before.

You see indications of the first everywhere, from newspaper reports on exciting new science results to school texts to the deliberations of funding bodies. The second is widely held among philosophers and is also endorsed by quite a few scientists, though it may not seem so much a part of the popular image of science. I think that with the exception of worries about how quantum theory fits in, the third is central to the popular image: it gives rise to all sorts of familiar conundrums about the possibility of free will: Are criminals – or even saints – really responsible for their actions? Will the final theory of everything allow us to predict the future with certainty? But, as I'll explain, it's hard to see why you'd hold with (3) if you didn't believe in (2), which is generally taken as the logical foundation for (3). That's why I've included all three, putting them in this order.

Let's look at each of these three in turn.

Science = Theory + Experiment

Children have been doing a lot of drawing during the Covid-19 lockdowns. Including my young granddaughter.

> 'Nan, how do you draw a scientist?'
>
> 'I don't know Tabi. I'm rubbish at drawing. Maybe we can get some help online.'

We looked for simple examples under 'cartoon scientists'. The most usual image is like Figure I.1.

Happily a few are like Figure I.2 (it's at last becoming more common for children to draw scientists as women).[1]

There are alternatives to pictures with test tubes and microscopes. Almost all are images of Albert Einstein.

Figure I.1 Typical children's drawing of a scientist
Drawn by Lucy Charlton especially for this book. Thanks Lucy!

Figure I.2 An increasingly typical children's drawing of a scientist
Drawn by Lucy Charlton especially for this book. Thanks Lucy!

(Oddly there are also images that look like Einstein, renowned for his famous theories of relativity, with a test tube – whereas Einstein didn't do experiments at all, let alone with a test tube.)

This suggests that the common image is: science = theory + experiment. This, for the most part, is what philosophers see too.

Figure I.3 Another typical drawing of a scientist
Drawn by Lucy Charlton especially for this book. Thanks Lucy!

It's All Physics Really

Tuesday, 27 April 2021, the *Guardian* newspaper published a three-page journal article, 'The clockwork universe'. The topic was science and free will. The *Guardian* notes that a 'growing chorus of scientists and philosophers argue that free will is an illusion'. The article looks to 'one of the most strident of the free will sceptics, the evolutionary biologist Jerry Coyne for a stark statement of the reason why: "free will is ruled out, simply and decisively, by the laws of physics"'.

This bleak view of nature and our place in it is an exact parallel of an image of science that is deeply imbedded in philosophical thought and that underwrites the bleak image of nature: the pyramid of the sciences, pictured in Figure I.4. Notice that all the sciences use the very same bricks as physics. And each falls under physics.

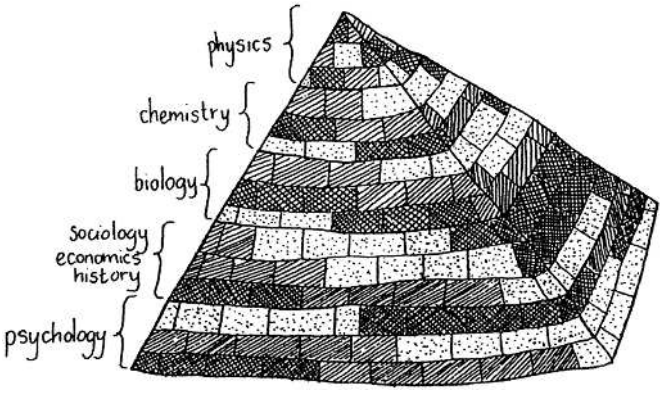

Figure I.4 The pyramid of the sciences
Drawn by Rachel Hacking and originally published in Cartwright 1999. Thanks Rachel!

Physics, they say, is the queen of the sciences. If you understand what physics does and how, then not only do you understand such grand stories as the motion of the planets and space-time curvature, you also understand everything that the other sciences have to teach, from chemistry and biology to psychology and medicine – at least you would if only you were clever enough to work it out. This is an image that has been favoured both in philosophy and in the sciences themselves. Consider for instance the great experimentalist at the turn of the nineteenth into the twentieth century, often called 'the father of nuclear physics', Ernest Rutherford. Rutherford is famously reputed to have remarked that '[a]ll science is either physics or stamp collecting'.[2] Historian and philosopher of science Hasok Chang, whom you will see challenging the reduction of physics to chemistry in Chapter 2, also quotes Rutherford, adding: 'It

may be considered fitting punishment that he was given the Nobel Prize in *chemistry* in 1908'.[3]

This story that everything is built from the building blocks of physics is often sold under the label 'the unity of science', as we see from the Cambridge Elements monograph titled *The Unity of Science*:

> The notion of the unity of science is regularly connected to the notion of reduction . . . . According to this line of thought, unity of science just means that fundamental physics is what everything else is ultimately based on; the . . . [other] sciences are somehow derivative.[4]

As you will see, philosophers have a lot to say about the whole idea of 'reduction' involved in getting from one science to another, but the pyramid still represents the dominant view. And after all, who could be opposed to unity? It is supposed to be a source of special strength: united we stand, divided we fall.

The Laws of Physics Fix Happenings Deterministically

What happens next follows inexorably from what's happened before – or so it is supposed. Physics rules everything and its laws are deterministic: for a given input, one and only one output is allowed under its laws. The inputs describe what's happened in the past. So exactly one future is allowed. Given that it's all physics really, this includes everything: all the happenings that occur in nature. Chemical properties, the way proteins fold, the look and feel of things, even your psychological states: their future is fixed since they are ultimately governed by the laws of physics. So, we live in a totally law-

governed world where things happen mechanically and even predictably if only we get to know what the laws are. That's how the world works. This is how those philosophers and scientists discussed in *The Guardian* arrive at the conclusion that, though we may feel strongly to the contrary, free will is an illusion.

You probably already know that this story about determinism and physics isn't entirely right. After all, there is radioactive decay. Whether a radioactive atom decays or not in the next hour is open – it may or may not. That is not fixed by the past. Still, not much is open. The probability that it will decay is supposed to be entirely fixed by past states. Nor can we – nor anything else – influence which it will do. What will happen will happen, willy-nilly. That can provide the comfort of certainty, but it's at the cost of impotence.

What's Wrong with These Three Images?

The idea of a law-governed world is now so entrenched that it is hard to step back and wonder why it is so at odds with the world as we see and experience it. Of course things are not always as they seem. But it is a big stretch from the world as we know it – a world where all the other sciences than physics make great discoveries and build impressive technologies, where we can and do make things happen and where sometimes things go as predicted but often not – to a world totally ordered from the Big Bang onwards under the undefiable rule of law and hence out of our control altogether.

Unease about these images increases when you look at what scientists actually do. It is much messier and more heterogeneous than the structured process of theory,

experiment and confirmation (or not) that is pictured in these common images. That process is about discovering the pre-existing but as yet not identified laws that govern the universe. To see science that way requires a lot of inventive imagination that goes far beyond what we actually see: what is manifest to us and to scientists as they go about trying to understand the world and how it works. If we look at what scientists *do* to produce the wonderful products of science that we so admire, like lasers, global positioning systems (GPS) and vaccines, they do not appear to be discovering laws and deriving results from them. It looks much more like crafting the pieces of a Meccano set and learning how to deploy them together, with a lot of trial and error.

The purpose of this book is to get a clearer perspective on how science produces things and why what it produces, from vaccines to spaceships, is so often so reliable. And that is very little to do with what these images suggest.

The book is titled *A Philosopher Looks at Science*. Note that it is not *Philosophers Look at Science* nor *Philosophy Looks at Science*. That's a good thing because philosophers are a mixed bunch. No two of us think the same thing. What I see when I look at science is not what 'philosophers' see, nor maybe not what the bulk of philosophers see. But it is what many of us see who look at the details of science as it is practised.

There's nothing controversial about the features and practices I shall highlight – no one would deny their role in science. These three popular images abstract away from these details. Of course, any image of science that is not an exact duplicate must do that. The point of abstractions like these is

not to provide an accurate summary of the details but to substitute a striking image that 'gets at the heart of what's going on'. The trouble is that these three do the opposite in my view. They conceal what it is that makes science so good at its job.

This book provides an alternative to these three common images. In it I look at science, and I also look at the world as seen through the lens of science. I focus on *what science does for us* and *how it does what it does for us*. The standard images are not well supported by a close empirical look at how science produces its amazing successes. To arrive at the standard story, it takes a good dollop of what philosophers call 'metaphysics' and what I earlier called 'inventive imagination' – sweeping claims far removed from concrete details we can get our hands on.

When I look at science I see a hotch-potch of finely crafted pieces brilliantly assembled in diverse ways to produce the myriad wonderful outputs science gives us, from understanding to technology, and that reflects behind it a dappled world, rich in diversity and where much is still possible. The image of nature that I read back from my look at science is one with space for the reality of contingency and for our power to effect change.

This book paints, one by one, alternative pictures to the three standard images of science that I have described and defends why I see science that way:

1.′ *Theory + experiment do not a science make*
It is not just theory and experiment. All the products of science play a crucial role in its successes: models; measurement definitions, procedures and instruments;