Introduction: scientific authority and the created controversy

The word *science* can conjure up for us a variety of ideas and images. It can whisk us back to cluttered classrooms, furnished with tall stools and long benches, Bunsen burners, and glass-doored cupboards stocked with assorted paraphernalia. The word might bring to mind the names and faces of famous scientists: Newton, Faraday, Hawking, Curie, Galileo and Mendel all jostle for attention, but ultimately are crowded out by a mental image of Freud and his cigar, Einstein and his untamed hair, or Darwin and an almost equally untamed beard. Maybe it rouses important scientific concepts, activities or instruments, the atom, star gazing, the test tube or the microscope. Perhaps we imagine a pristine laboratory, a young technician dressed in an immaculate white coat, scrutinizing a vial of blue translucent fluid for reasons unknown.

Science is ubiquitous. Its boundaries are fuzzy, its range bewildering. Distinctions have been drawn between different *types* of science, natural versus social, hard versus soft, historical versus experimental, and so on. Disagreement reigns over whether economics is science, whether anthropology is science, whether history is science. Creation science calls itself science, but many call foul. Politicians have suggested – what sounds thoroughly reasonable – that policy should utilize *sound science* and eschew *junk science*. Scientific discoveries are reported in the media; scientific concepts are utilized in novels, film and television. Science is popularized and demonized. It offers explanations of our most commonplace observations, but in terms that are peculiar and hard to comprehend. Scientific developments are integral to some of society's most remarkable achievements, but also some of our most horrifying tragedies. Science is both utterly familiar and an immediate source of controversy and debate.

The fact that science occupies an extraordinarily important place within modern society makes it important to think more carefully about what science is. A great deal of scientific research is conducted in service to issues of public safety and perceived public need, is funded by taxpayers, and is overseen at least to some extent by political systems. It is sensible to consider whether the research being pursued is of genuine value, of greater value than research that doesn't get funded, and whether the degree of political oversight is appropriate. The technological fruits of scientific labours often give rise to hard questions about the ethics of warfare, human reproduction, food production, energy development and more. To some extent at least science interacts with every other aspect of society, and at each point of interaction there is room to evaluate whether sensible goals have been identified, and whether sensible methods are being deployed with respect to those goals.

The *applications* of scientific research generate critical questions, but even if we restrict our attention to science as it seems principally concerned with generating facts, or knowledge, or information, our preconceptions deserve closer scrutiny. Insofar as the laboratory white coat seems emblematic of science, do we forget those scientists who work predominantly in the field, or at a computer, or with human subjects? Do we regard some of these activities as *less scientific* and, if so, on what grounds? Newton and Galileo are famous figures from the history of science, but how sure are we that today's scientists would agree with them about what counts as science, and how science should be conducted? Distinguishing scientific from non-scientific disciplines sounds like a sensible and worthwhile endeavour, but significant efforts have accomplished little consensus among philosophers of science; neither the struggles, with what's known as the problem of demarcation, nor their implications, are widely appreciated. Thus, even ignoring the broader roles of science in the modern world, attempts to understand the nature of science – its methods, assumptions, limitations and achievements – prompt difficult questions and sensible concerns. Making sense of even this much is important, as we'll see, but not straightforward (as we'll also see).

Regardless of where precisely we define or find its edges, however, and what exactly we imagine happens between them, most of us appear, at least most of the time, willing to admit science as our most reliable means of acquiring knowledge of both ourselves and the world we inhabit. Scientists are our most respected authorities on an incredibly wide variety of issues. We look to them for answers concerning the deep past and the near future, the living and the inanimate, the farthest reaches of the universe and the innermost secrets of the human mind. An enormously diverse range of subjects are lumped together under the banner of science, and one of the few attributes these subjects share in common is that *because they're science* we attach special significance to their conclusions. We assume science is more *objective* than alternative ways of investigating the world, that it is guided by *facts* and thus less influenced by fads and impulse, its results unvarnished by personal agenda, prejudice and bias. By overcoming biases science is considered more *rational* than alternative ways of investigating, and thereby achieves something that is absent from many other human activities: the histories of literature, art, and music contain ample evidence of change, but science seems to do more – it makes *progress*. Our confidence in its methods means we trust science to tell us how things are, at least most of the time. The reason it is sometimes thought important whether psychology, for example, can properly be called a *science* is that the term has significant rhetorical force; merely labelling a discipline *scientific* can improve its profile and credentials, hence the occasionally bitter disputes over whether a particular discipline deserves the honorific.

The confidence we place in science deserves close inspection. Can we justify our preference for distinctively scientific conclusions? Can we identify those features that make science more rational and more objective? As we'll see, that science is purportedly more objective, more rational, based on facts, and so on are ideas that have all been challenged. In the early 1960s a fresh approach to questions about the nature of science revolutionized philosophy of science and neighbouring disciplines, and influenced many more distantly related fields. Some who were stirred by the new methodology advanced yet more radical challenges during the 1970s and 1980s, which ultimately led to what the media dramatically dubbed *The Science Wars*. What appeared to be at stake was nothing less than scientific authority itself – that widespread assumption which admits science as our most reliable means of generating knowledge. Many would defend a triumphal, laudatory attitude towards science, but others were far less sanguine. In subsequent chapters, we'll discuss, in broad outline, both the evolution of these ideas and their foundations.

Despite the influence of these sceptical attitudes towards science, in many circles, and in many contexts, scientific authority remains unsullied. Even putting radically sceptical attitudes towards science aside, however, the authority of science can still seem somewhat surprising if we pause to reflect on some modern scientific conclusions. Physics and chemistry trade in objects that seem almost impossibly small. Consider that there are more atoms in a grain of sand than there are grains of sand on almost any given beach. (Read that sentence again if at first glance it seemed just too incredible.) Cosmology and geology deal with events on enormous scales, both in space and time, and processes that take so long to unfold that the entire history of mankind is negligible by comparison. Compress the history of Earth into one calendar year and the birth of Jesus Christ occurs with less than fifteen seconds of the year remaining. (You might try pondering on that when you're about to begin the countdown next New Year's Eve.) Molecular biologists tell us that the information needed to create something as complicated as a human being is contained within twenty-three pairs of chromosomes, that two copies of each chromosome can be found in almost every cell in your body, but most of these cells are so small that they're invisible to the naked eye. Einstein's theories of special and general relativity, quantum physics, neuroscience, biochemistry, evolutionary biology, and a great deal more besides, can simultaneously stupefy and delight. Science presents us with a fascinating description of the world, often highly unexpected, and sometimes so mind bogglingly bizarre that it stretches credulity.

Yet in spite of its astonishing conclusions most of us appear willing to accept most scientific claims without fuss, perhaps through familiarity, or a tendency to massage the claims into a more digestible form. The truly remarkable nature of some of science's most important discoveries can be easily overlooked, but should serve to illustrate that our personal intuitions, speculations and extrapolations from familiar experiences, our common-sense judgements, and even just our very best efforts to think really hard, rarely produce results that even remotely approximate the scientific image. Conceding the authority of science requires that we relinquish the right to reject scientific conclusions just because they don't sit right with us. If our gut reactions were a reliable guide to the plausibility of scientific conclusions, then scientific successes wouldn't keep building on ideas that at first sound preposterous. That our planet spins on its axis at hundreds of miles an hour, and completes an annual orbit of the Sun, were deeply disconcerting ideas to Galileo's contemporaries in the early seventeenth century. The size of the universe that was needed by the heliocentric model, to account for the absence of what's known as stellar parallax, was nothing short of astounding.[1] The discomfort felt by those who were challenged by Galileo was in itself an unreliable reason for rejecting heliocentricism. Mere discomfort isn't a better reason for rejecting a scientific conclusion today.

Nevertheless, on a wide range of issues many people are accused of dismissing well-established scientific claims, despite the absence of any good reason for doing so. Advocates for certain scientific ideas insist that the science is now beyond dispute, and that its main conclusions can't be ignored. Those who continue to resist these conclusions are accused of relying on superstition, or wishful thinking, or simply of being ignorant and confused. Science proponents insist that too many people, without relevant qualifications or understanding, trust their own ability to evaluate the state of the science above the combined acumen of scores of experts. And the result is more serious than simply a misinformed public. By ignoring our scientists, it is suggested, we are risking our health and the health of our children, flirting with unprecedented environmental disaster, and thereby incalculable human cost, embracing naïve attitudes about the world around us, denying ourselves technological advances that hold the potential for momentous improvements to our quality of life and unnecessarily endangering members of society that deserve far greater protection. Throughout this book I'll assume that such consequences are bad and that we should be motivated to

[1] It's familiar from everyday experience that objects change their apparent position, relative to more distant objects, as we change our perspective. For example, with just one eye open, hold your thumb out at arm's length so that it fully obstructs your view of some object. Now switch eyes and the object becomes visible, with your thumb located some distance to the left or right of that same object within your visual field. The change in perspective affects the apparent position of your thumb, relative to the more distant object. If the Earth orbits the Sun, then our perspective on any given star changes. Stars that are closer should, therefore, appear to change their positions, relative to more distant stars. These effects are now discernible, but the technologies available to Galileo were insufficient to reveal this effect. Heliocentricism was reconciled with this failure to observe stellar parallax by supposing that even the closest stars were much farther from Earth than anyone had previously believed. The change in perspective, as the Earth orbits the Sun, thus becomes negligible relative to the distance to the stars, and hence the absence of stellar parallax is explained.

avoid them. Since I imagine that most readers would agree on both scores, the more important questions become: Are we really ignoring well-established scientific opinion without good reason, and, if so, how is this happening? How sure are we that science has got it right? Science has been wrong before, so why should we trust what today's scientists say? Furthermore, with respect to many scientifically informed, hot-button issues, like climate change, homeopathy, stem cell research, evolutionary biology, the safety of vaccinations, and so on, we are often aware of objections to the science, and to the presence of dissenting voices seemingly from within the relevant scientific community. In some instances, we might suspect that certain scientists have an agenda to promote their ideas regardless of the quantity and quality of the evidence that's available to them. Although some insist the science is unassailable, isn't it reasonable to still have doubts and concerns about even the most basic conclusions?

The stakes are high. Needlessly risking our health, our lives, and our planet, is something we all wish to avoid, but if the science is wrong, then endorsing its recommendations will also have avoidable and perhaps devastating consequences. We must strive to make decisions, whether on a personal, regional or global level, that are based on the best information we have, and hence we can afford to ignore prevailing scientific conclusions only if we have good reasons for doing so. In this book, we'll be concerned to learn how we can better evaluate the state of debates that are advertised as scientifically controversial, and to see what kinds of objections to scientific controversy are worth worrying about. In part this is a book about how we have been led astray on certain issues, and what we can do to avoid being misled again. We'll seek to improve our critical thinking skills and better appreciate some of our shortcomings as rational agents. We'll look to philosophy of science for help in developing more sensible attitudes towards the nature of scientific inquiry and, in the final chapters of the book, towards particular issues surrounding matters of public health, as well as climate change and Creation science. Reviewing an example now, however, will help better illustrate some of the book's principal themes; a particularly instructive example concerns the conduct of the tobacco companies during the middle of the twentieth century.[2]

The cigarette deception

The first machine-rolled, modern cigarettes appeared in the 1880s. Almost from their inception there were concerns about possible health risks. The effects of smoking on circulation, physical and mental development, as well as fertility and lactation in women, were all explored during the first few decades of the twentieth century, but

[2] The actions of the cigarette industry during the second half of the twentieth century are very well documented. Brandt (2009) and Proctor (2012) are excellent resources.

studies produced only ambiguous results. Excessive smoking was generally judged inadvisable, although it was unclear exactly what qualified as excessive. Smoking was also widely regarded as harmful to children, though this was seemingly based on little more than suspicion. Largely, however, medical opinion settled on moderate smoking as a safe practice for most adults. The fact that cigarettes increase the risks of developing lung cancer owed its discovery to several factors. Allan Brandt, a historian of medicine, argues that one of the most important factors was the introduction of new statistical methods into medical research during the late 1940s, methods that were introduced by the very researchers who were curious about the cigarette-lung cancer connection.

During the early decades of the twentieth century, the study of disease was dominated by laboratory-based techniques. The German physician, Robert Koch, had advanced four principles for identifying the causes of infectious disease. If a certain microorganism is found predominantly in organisms diagnosed with a given disease, and can then be isolated from the diseased organism and grown in culture, utilized to induce disease in an otherwise healthy organism, and, finally, isolated from the inoculated organism and shown to be identical with the original microorganism, then we can conclude that this particular type of microorganism causes the particular disease. Koch's postulates were hugely influential, although recognized even by Koch as having significant limitations; they also played an important role in the more general, dominant penchant for studying disease at the cellular level. An important implication of this preference for laboratory methods was the marginalization of statistics within medical research.

In 1950 two important papers were published, one by American researchers, Ernst Wynder and Evarts Graham, and a second by British scientists, Bradford Hill and Richard Doll.[3] These presented impressive statistical evidence relating cigarette smoking to lung cancer. Within their sample populations, lung cancer was extremely rare among non-smokers, and cigarette use was high among those diagnosed with lung cancer. Among lung cancer patients, the high ratio of males to females was attributed to the fact that smoking had been a predominantly male activity. The evidence was, however, as the authors were only too aware, *merely* statistical. The use of statistics is by now so common that it's hard to appreciate how things could ever have been otherwise. Nevertheless, within the medical profession, overcoming scepticism and resistance towards the connection between cigarettes and lung cancer involved, in large part, convincing the medical community that statistics could provide a legitimate form of scientific evidence.

What's easy to overlook, in our efforts to better understand the nature of scientific inquiry, is that some scientific debates concern the propriety of particular *methods*.

[3] In the 1930s German and Argentine scientists had gathered evidence that cigarettes cause lung cancer, both through animal experimentation and statistical studies, but these were largely ignored. See Proctor (2012) for more details.

This is a failing that has important implications for our understanding of scientific controversies. For example, if scientific communities need persuading of the cogency of new approaches to traditional questions, then it is incumbent on us to learn more about those methods before we can justifiably dismiss the resultant conclusions. Second, cases like the cigarette controversy speak against the idea that science employs an unchanging set of methods: the ways in which science generates knowledge are themselves prone to revision. If scientific methods change, then what constitutes *good science* must also change. Establishing the connection between cigarettes and lung cancer involved an expansion of what qualified as good medical research. If the standards by which we evaluate science are susceptible to change, however, then an important incentive for distinguishing scientific from non-scientific research dissipates. In Chapter 1, we'll return to this idea when we consider the infamous problem of demarcation, and ask whether attempts to resolve the problem are a worthwhile exercise.

Returning to our historical narrative, in 1950 a number of prominent, qualified researchers were unconvinced by the initial statistical studies, but more studies followed and the evidence mounted. Lung cancer rates didn't vary between rural and urban areas, undermining the idea that air pollution was responsible for the rise in reported cases of lung cancer. Laboratory studies on mice corroborated the idea that something in cigarette smoke was carcinogenic. By the mid-1950s there were very few qualified experts denying that there was an important causal connection between cigarette smoking and lung cancer. The U.S. surgeon general was convinced. Leading medical associations were convinced. The response of the tobacco industry was swift, shrewd and hugely formative when it came to shaping *public* perceptions.

Cigarette companies were already tremendously adept at influencing public attitudes towards their product, having developed a variety of innovative, and highly effective, marketing strategies and advertising campaigns. (Cigarette companies are often credited with having essentially launched the marketing and advertising industries.) Such skills were now utilized and refined in response to the new science-based threat. Early advertising campaigns encouraged smokers to conduct their own personal tests and to see for themselves that a certain brand didn't cause throat irritation. Individuals were thereby urged to trust their own judgements over the science. With hindsight, we recognize the folly of those who thought that their personal experience with cigarettes could provide more reliable evidence than large population-based studies, but we will see later that the habit of dismissing science in favour of personal experience persists.

Fairly quickly, however, the strategies of the tobacco industry shifted. Rather than seek to undermine *science*, and promote confidence in personal experience, the cigarette companies sought to undermine the idea that there existed a scientific *consensus*. Rather than distance itself from science, and criticize scientific research from afar, the industry sought ways to achieve sufficient scientific credibility that they could corrupt from within. The industry gambled on the idea that creating the appearance of uncertainty within the scientific community would provide smokers with sufficient reason to continue smoking and many non-smokers insufficient reason not to start. If tobacco could successfully infiltrate the scientific process, then people could no longer look to science for answers; tobacco would create the impression that science had no answers, but offered only confusion and uncertainty. As one tobacco industry CEO would famously remark, 'Doubt is our product.' Uncertainty and doubt play a significant role within the kinds of debates we'll discuss later in the book. The absence of certainty surrounding a given conclusion is quite consistent with having very compelling evidence for that same conclusion. In certain circumstances, however, we can all display a strange tendency towards supposing that if no-one knows for *certain*, then no-one knows at all, and hence that any opinion on a given issue is as sensible as any other. Clearly we must learn to respond more responsibly to the appearance of doubt.

A 1953 statement, released on behalf of the major cigarette manufacturers, described their belief that cigarettes were not harmful, and their commitment to continue ensuring rigorous safety standards. Funds were promised by the industry, and were forthcoming, for additional research. Several decades on and it's clear that the projects which received industry funding were far more concerned with genetic and environmental explanations for lung cancer, and thus possessed greater potential to reprieve cigarettes than to generate additional evidence of blame. More important, by funding scientific research, even research over which they had a large degree of control, the tobacco industry bought itself a measure of scientific legitimacy, which could then be leveraged to create the appearance of a genuine scientific debate. Keeping the debate alive kept uncertainty alive. Keeping uncertainty alive helped sustain the tobacco companies' agenda.

The industry's scepticism was dressed up to fit familiar scientific virtues: according to the cigarette companies it was too early to offer definite conclusions about the connection; more studies were needed, as well as calm, careful analyses of available evidence. Such cautionary attitudes and requests for more research can sound eminently reasonable, by science's own standards. Those who were insisting that cigarettes were responsible for the increase in reported cases of lung cancer were portrayed as alarmist and irrational. Those scientists who disputed the majority view of health professionals were few in number, but the industry worked hard to publicize their opinions and puff their reputations. In general, as long as some scientists were willing to repeatedly dispute the connection between cigarettes and lung cancer – no matter who paid their salary – the public would hear that some scientists were convinced by the evidence and some were not.

The story of tobacco companies' deception is a familiar one, but there are morals we should be mindful of. A rallying cry of industry scientists was that there was *no proof* that cigarettes caused lung cancer. As we'll see in Chapter 2, however, we must be careful with our use of the word *proof* when discussing scientific claims; observing that a given conclusion has not been proven appears noteworthy only because of a subtle ambiguity in language, which reflecting on the nature of science can quickly dispel. A second conspicuous strategy of industry scientists drew attention to issues that weren't understood, with the hope of promoting uncertainty more broadly. What prompts people to start smoking? Why do some smoke more heavily than others? Why do many smokers suffer no ill health? Until we could remove such uncertainties, it was argued, it is imprudent to draw any conclusions about the state of the debate. But the argument is unpersuasive: we can achieve very good evidence that smoking causes lung cancer without having a good explanation for why people become smokers in the first place. Emphasizing what's not well understood by science is an effective means of *magnifying uncertainty*. By magnifying uncertainty groups can undermine public confidence in a much broader set of ideas. We will inspect the strategy more closely in Chapter 7.

Industry spokespeople employed double standards, according to whether studies spoke for or against the risks of smoking: evidence for the connection between smoking and lung cancer were held to impossibly high standards, but the idea that smoking is therapeutic was promoted without any serious evidence whatsoever; animal studies that suggested cigarettes were harmful were dismissed as uninformative on the grounds that what's true for mice is an unreliable guide to what's true for humans, but when animal studies purportedly provided favourable evidence for the industry, these were touted as important and telling. On behalf of cigarette companies, it was often noted that non-smokers did sometimes develop lung cancer and that many individuals smoked heavily throughout their lives seemingly without consequence. How, it was argued, could lung cancer thus be attributed to smoking? The argument commits a classic informal fallacy, known as the straw man fallacy. No-one claimed that all and only smokers would develop lung cancer, only that smoking increased the risks. We'll look at a variety of such fallacies in Chapter 6.

The industry promoted its own scientists, ideas and arguments, aggressively and persistently. For every article, report and editorial sympathetic to the mainstream wisdom that smoking caused lung cancer, the industry ensured that there appeared a rebuttal. The state of the science was often misrepresented: that cigarettes cause cancer was criticized for relying on merely statistical data, even though notable evidence from pathological and experimental research had been provided. Many of these tactics exploit important mechanisms by which we all evaluate claims and conclusions. The wishful thinking fallacy provides a plausible explanation for differing attitudes towards the risks of smoking, as held by smokers versus non-smokers. A 1991 Gallup poll reported that 91 per cent of non-smokers accepted smoking as a cause of lung cancer, compared with just 69 per cent of smokers.[4] Understanding more

[4] If this is an example of wishful thinking, then the diverging responses arise because people's desires and hopes are influencing what they believe. An alternative explanation for the polling results suggests instead that people who are

about our cognitive tendencies, and how they can sometimes lead us astray, can facilitate better evaluations of available evidences. We will briefly survey some recent work in cognitive psychology in Chapter 5.

By the mid-1950s, the medical community was in little doubt about the risks of smoking cigarettes, but cigarette companies continued to magnify uncertainty and doubt. According to a 1954 Gallup poll, 90 per cent of those surveyed were aware of reports that cigarettes may be a leading cause of lung cancer but, even by 1960, only 50 per cent accepted that cigarettes do cause cancer. It would be easy to feel smug when we reflect on all those who failed to recognize what by now seems so obvious, to shake our heads in disbelief that so many were so atrociously duped. However, we must be careful not to underestimate the enormous difficulties that were overcome by those who rendered this fact scientifically credible. We should be just as careful not to underestimate the obstacles overcome by those who convinced a sceptical public, obstacles that were largely erected and maintained by the remarkably well-funded, savvy and determined tobacco industry.

There are unquestionably a variety of factors – psychological, social and political – responsible for the success of the cigarette in the second half of the twentieth century, in spite of the incontrovertible evidence that described its grave health risks. Part of the explanation, however, is the public perception that the science was unsettled. There are many who would argue that the public is being similarly fooled, on a variety of issues, by the same tricks that tobacco did so much to develop. Consequently, there are important lessons to learn from the cigarette deception, lessons that can help us distinguish genuine scientific controversies from the mere appearance of controversy, lessons in critical thinking and the nature of scientific research, lessons that can help us all make more informed decisions.

A role for philosophy of science

Scientists are expert in the discipline they have been trained in. Their training and education introduces them to a wide range of techniques, methods, concepts, problems, solutions and problem-solving strategies. Philosophers of science may spend some of their time thinking about the same concepts, methods and so on, but philosophy of science is more centrally occupied with more general questions concerning what science is, what it achieves and how science differs from other ways of exploring the world. As we'll see throughout the book, when it comes to drawing conclusions about the state of a particular scientific issue, many of our most common mistakes stem from ignorance of how science works rather than ignorance of the science itself. For the purposes of utilizing scientific information responsibly,

unpersuaded that cigarettes cause lung cancer will be more likely to smoke. I leave it to readers to ponder on which explanation likely applied most broadly.