Chapter 8

Knowledge vs Insight

Michael Polanyi was one of the world's leading physical chemists in the first half of the 20th century, and a leading philosopher of science in the second half of that same century. His experimental and theoretical work on gas adsorption by solids (activated carbon to begin with), on which he first published during the Great War (1914–18), is still being referred to and used to this very day. The Polanyi theory has been recognized as one of the most powerful theories for dealing with both gas and aqueous adsorption on heterogeneous solid surfaces. In his defense of his specific theory of adsorption in the first decades of the 20th century, however, the mainstream scientific community rejected his ideas in favor of the work done by Langmuir, despite the fact that his theory carried strong experimental papers. That changed in the 1950s and 1960s. Interestingly, while reflecting, as a philosopher of science, on his initial failure to convince the scientific community of his approach, he stated in his 1963 *Science* article that "at all times [there must be] a predominantly accepted scientific view of the nature of things, in the light of which research is jointly conducted by members of the community of scientists. A strong presumption that any evidence which contradicts this view is invalid must prevail. ... The dangers of suppressing or disregarding evidence that runs counter to orthodox views about the nature of things are, of course, notorious, and they have often proved disastrous. Science guards against these dangers, up to a point, by allowing some measure of dissent from its orthodoxy. But scientific opinion has to consider and decide, at its own ultimate risk, how far it can allow such tolerance to go, if it is not to admit for publication so much nonsense that scientific journals are rendered worthless thereby." Within this age of informatics available to all, yet not always easy to get to grips with by specialists and nonspecialists alike, Polanyi gives us ample material to reflect upon. Here, we will try to order some of the issues the field of toxicology is confronted with.

THE WORLD AT LARGE

As we have shown in the previous pages, chemistry is everywhere. And it has a myriad of effects on us in untold ways. In toxicology we try to fathom these exposures and effects. For that, many different research fields are tapped into from chemistry to biology, from pharmacology to medicine, and

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also from food science to healthy diets and from toxicology to hazard identification and risk regulation, etc.

Clearly, the identification of hazards of chemicals, as discussed earlier, seems to be of prime importance in our precautionary culture. Risks of chemicals exposure of especially the man-made kind need to be banished as much as possible: better safe than sorry. That has, to some extent, driven the growth of scientific research into the risks of modernity, in which chemical risks play a notable part.

Subsequently, thousands of scientist toxicologists publish their findings in many different peer-reviewed journals. Their scientific careers, in large part, are built thereon. Better, these findings need to be made available through the media to the general public as to make one's research more relevant. Once talked about in the press, academic standing increases and thereby the chance to get grant proposals accepted.

It should not be surprising that the theme of risk plays a prominent role in these public outings. Nowadays, many different risk issues take front page: killer asteroids, global influenza, fertility risks because of pesticides on our veggies, and so on. We are continually warned that, for the human race, "time is running out" unless we do something about global warming or climate change. "The end is nigh" is no longer a warning issued by the religiously inclined, far from it. In fact, scaremongering is increasingly represented as an act of concerned and responsible citizenship. And scientists are among those responsible citizens.

But there are problems. To begin with, the number of specialized academic journals and published articles is such that it is impossible for anyone to keep track of, including the academic specialist. Moreover, it seems that only a handful of people, usually colleagues, will ever read those individual articles. Even fewer articles will ever make it to the general public through the many different media outlets—national and local newspapers, magazines, news websites, blogs, vlogs, and so on. And that fact alone does not carry any seal of quality. Indeed, the bias toward risk is well understood by many as a means to come into the spotlights of public attention. So-called "fake news" is the talk of the town and how to identify it as such is no easy task.

All sorts of (selected) information are available to almost all, yet weighing its relevance is far more difficult. Additionally, in what ways are the topics that toxicological research focuses on governed: by regulatory agencies, media, fear (see the previous chapter), politics, public awareness, or internal academic drivers such as curiosity, professional responsibility? Are hazards and risks the main drivers therein? And how do we sift through the available material and make coherent sense of it all?

An analogy with the definition of health we defend in this book seems to be applicable here. If the ability to adapt is the defining character of human health on the biological level, then the ability to keep one's mental health should be driven by a "reasonable" homeostasis with the outside world of (dis)information to which we are exposed. That, however, requires some

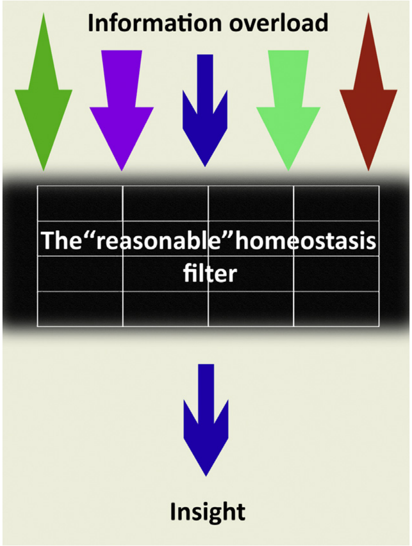

FIGURE 8.1 Picture of information overload and the "reasonable" homeostasis filter (see further below).

kind of "mental mechanism": discarding the junk and keeping the good stuff as not to poison ourselves with disinformation (Fig. 8.1).

Such a mental mechanism should be available not only to the specialist but to everyone. We will propose three insights from the philosophy of science and will subsequently rework them into some straightforward "tools" and apply these to a few examples from the realm of toxicology that reached the spotlights of public and political attention.

Overall, we should be wary of the law of inverse rationality. We can be sensibly rational at the fringe of our interests, where the prospect for prideful self-assertion is limited. Conversely, when a certain topic approaches the core of our being—our wealth, health, safety, security, and longevity—the greater the probability, that truth will be subsidiary to other values (e.g., human autonomy, self-preservation, fear, power). We will explore this further in the following section.

OF SCIENCE AND THE WORLD—THREE INSIGHTS

It might seem that we have wandered into the field of neuroscience and related topics in order to understand the "mechanism for mental health," if we could identify some such. That is not the case. What we do here is formulating a few notions—insights—that could be a means to evaluate scientific statements that capture the imagination of the press, the public, policymakers, and the like. These insights are derived from the philosophy of science. *They invite to be attentive, intelligent, critical, and responsible.*

The corollaries of the insights will be subsequently expressed in some tools. These could help the nonspecialist through the endless news items and policy prescriptions related to the benefits of certain foods or food supplements, the purported dangers of rubber granulate-containing artificial turf to young soccer players, the risks of sunlight in general and sunbathing in particular, the occurrence of child leukemia ostensibly induced by nonionizing electromagnetic fields, say, from overhead power lines, and so on.

Science is usually understood as empirical in nature (although mathematics and (scientific) reasoning cannot be reduced thereto). Through experimentation one tries to establish basic regularities of the world (Fig 8.2). What the empirical sciences produce are *contingent* propositions, that is *not necessarily* true or false: "chemical A interacts with protein X resulting in effect Y"; "the element thallium has the atomic weight of 204.38"; "the lethal dose of X for mice is Y"; "the consumption of this food adds to our health and longevity".

These and many other propositions generated by the empirical sciences are all *conditionally* true, given various facts and evidence. None of these propositions are logically necessary. It is logically possible for these statements to be false, say, due to measurement errors, mistakes in experimental setups, incorrect starting materials, the limitations of available facts, and so on. Thus, scientific arguments start from empirical premises and draw only probabilistic conclusions, prone to correction. To be sure, we do not doubt

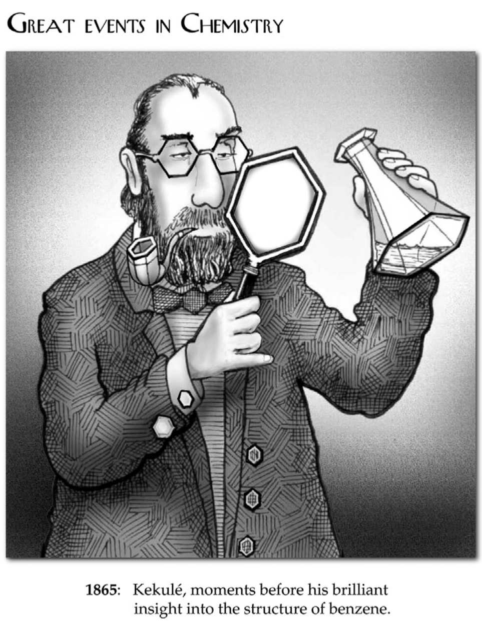

FIGURE 8.2 Friedrich August Kekulé moments before "discovering" benzene (Nick D. Kim http://scienceandink.com/).

the measurements of the atomic weight of thallium, for instance. The premise of trust is ever present, and quite rightly so. But, as the business of science expands, this premise is undermined, as we will see.

Here, the *first* insight emerges: no scientific results will give us *definitive* answers to our many questions. Many scientists, perhaps following too closely the citizen or policy cheering section, developed the risky habit of insisting that their *conditional* truths are *necessary* truths. Some have gone further downhill by insisting fallaciously that their probable truths are universally true. The compelling statement "science has shown that . . ." should be taken with a grain of salt, and sometimes perhaps even more than that, say, a truckload. Wholesome skepticism thus is a balancing act, as Polanyi showed, between orthodoxy and dissent, between the quietist "everybody knows that . . ." and the twitchy "forget everything you know about . . .".

To be sure, ignoring counterevidence in order to maintain the theory under investigation is not uncommon among scientists, and that may be the right way to respond. This is not just a rationally informed decision. The passionate commitment informs the scientist to stick to his guns. The institution of science could hardly survive if all or most members made it their aim to falsify theories in the sense of trying to generate anomalies. Progress in science requires that most scientists get themselves in the grip of a theory which they aim to develop and defend it, without simply trying to dispose of it as quickly as possible. This might equally result in the scientist overshooting the mark in order to avoid professional embarrassment when he persists with an increasingly unmaintainable theory.

The *second* insight, incipient in this debate on (the limits of) commitment, seems, at first glance, to conflict with the first one. That, however, is unwarranted. There is much more to scientific results than merely some viewpoints expressed by experts. We *can* and *do* have a sense of understanding of the world that exists independently of our current knowledge.

But, that requires that we steer well clear of two notions that undermine any attempt to try to come to such growing understanding. One is the false belief that "everything is an opinion" whereby all utterances of human understanding are no more than personal edicts that by definition cannot be contested. After all, here there is no frame of reference that surpasses the personal. The other is the equally false belief that human inquiry can become all-encompassing explicitly with the aid of science. This is also known as *scientism*: that is the fallacious idea that only one type of human understanding—science—is in control of the entire universe *and* what can be said about it (Fig. 8.3).

The philosopher Thomas Nagel gave fair warning about our understanding of the world around us that captures both contradictory aspects of our culture that seem so far apart yet are so closely intertwined: ". . . for objectivity is both underrated and overrated, sometimes by the same persons. It is underrated by those who don't regard it as a method of understanding the world as it is in itself. It is overrated by those who believe it can provide a complete view of the world on its own, replacing the subjective views from

FIGURE 8.3 In science we trust.

which it has developed. These errors are connected: they both stem from an insufficiently robust sense of reality and of its independence of any particular form of human understanding."

The term "objectivity" involves some kind of impartiality, a lack of bias, basically distinguishing between two ways of forming beliefs about the hidden structure of the world. One way depends on, say, caprice, prejudice, expectations, power, pride, wealth, fear, etc., the lower nonepistemic interests, and drivers that are *unrelated* to genuine knowledge gathering. The other avoids such inacceptable influences. But just avoiding these pitfalls simply won't do.

Doing proper science involves robust ethical and fiduciary-type commitments: there is no discovery in science without the passionate aspiration *to know*, and a belief (as in trust) that there is something out there *to* know. Passion, love, and faith (again, as in trust) sustain the method of science *a priori*, providing for the higher interests (in contrast to the lower ones stated previously) scientists need to embrace to actually become good scientists. Clinical cold-eyed realism demands all manner of epistemic virtues, that is related to the gathering of knowledge: openness to being wrong, selflessness, humility, generosity of spirit, hard labor, curiosity, tenacity, a readiness to collaborate, conscientious judgment, transparency, and the like. For the famous philosopher Thomas Aquinas, all such virtues have their source in love. Love is the ultimate form of undeceived realism. That is why it is intimately related to truth (Fig. 8.4).

This brings us to the *third* insight. A scientist faithful to the scientific ideals of judiciousness and honest self-criticism will present her or his results with humility and an acute awareness that the world out there is much bigger than the results presented. Drawing conclusions that go far beyond the published work is a sure sign of an overestimation of what can actually be said.

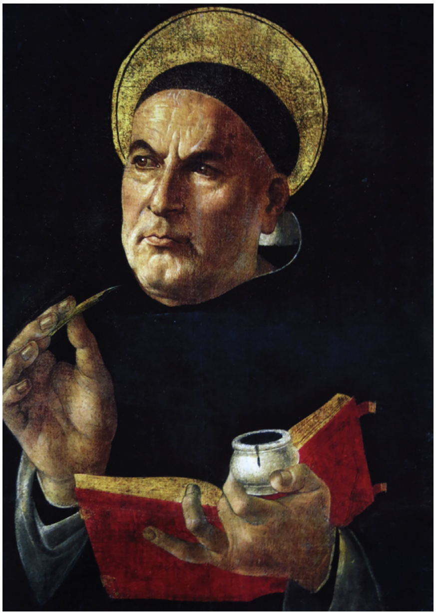

FIGURE 8.4 Thomas Aquinas by Sandro Botticelli. *From Granger—Historical Picture Archive.*

The context within which the presented work figures is essential, and without it judging the quality of the published material, even superficially, is almost impossible to do. Cherry picking (also known as the exception fallacy), that is basing general conclusions on a minor subset of cases, is a real-world problem and a big one to boot.

These three insights give leeway to a number of "tools" that could add to a general understanding of scientific information that finds its way to mainstream media and Internet websites everywhere. Lest we forget, both institutionally and personally, science is looked at as a discerning field of advice in terms of numerous aspects of life, such as geographical position and direction (think of the Global Positioning System), human health (medicine, food security and safety, nutrition and health, particulate matter air pollution, cell phone radiation, etc.), parenthood (the "nanny shows" with its pedagogical experts once were broadcasting blockbusters). We increasingly believe that experts can inform us reliably and definitively about the status of the world with respect to many central characteristics of our personal and corporate lives. And the idea that that is compulsory is typical for precautionary culture we discussed in Chapter 5, From Prevention to Precaution—Valuing Risks.

THE "REASONABLE" HOMEOSTASIS—SOME EXEMPLIFIED TOOLS

Thus, the scientific endeavor, however incomplete, is focused on probing the hidden structure of reality—of atoms and molecules, of proteins and organs, of neurology and psychology, of social relations and politics, and so on. Results, which give insight into the world we live in, are nevertheless conditional and always open to extension or even partial or complete revision. If scientists are to be successful in delivering insights with proper objectivity and humility, then our knowledge base will grow steadily, with its backwards and forwards included.

However, the precautionary drive toward (scientific) surety about the world and us—related to our safety, security, health, and longevity—embeds a number of shortcomings into the scientific institution that surface once the three insights mentioned are confronted with this drive. Here, a few tools, based in part on the work done by Ioannidis, are presented to appraise claims made by the scientific community, while not being a specialist. We deliberately state the tools in the negative form as a device to reverse the seriousness with which scientific results are sometimes presented. These tools should not be understood as directly causal: "if . . ., then . . .". Rather, they are indicators to make nonspecialists aware and critical of the research results presented. The question "But is it true?" should always be in the back of one's mind, whether a specialist or not.

1. *The smaller the effect sizes in any scientific field, the less likely the research findings are true (insights 1, 2, and 3).*

   Scientists are increasingly obliged to target smaller effect sizes purportedly related to everyday agents to which we are exposed. Usually, the potential effects of certain agents are theoretical: they are derived from models without actually observing those effects in human populations. In fact, such observation is impossible as any effect, if at all existent, is simply far too small to actually measure. Think for instance of the proverbial singular carcinogenic molecule, as discussed in Chapter 6, Molecular Trepidations—The Linear Nonthreshold Model, being able to cause cancer in an individual after exposure.

   The result is, so the story goes, insight into how we can protect ourselves from even the most mundane risks. This has been called the "epidemic of apprehension." And this epidemic grows with each new alarm about a new "menace in daily life." Although this notion was first put forward by Alvan Feinstein some three decades ago, this purported menace has grown, aided by our precautionary propensities.

   The exposure to radon—a radioactive noble gas that is exuded by natural stony materials such as granite but also building materials—and the prevalence of lung cancer are examples here. In 1999, considering the approximately 157,000 lung cancer deaths occurring annually in the United States, radon was *computed* to play a role in about 15,000−22,000 cases.

   In 2005, many news outlets in the Netherlands reported that particulate matter (PM) air pollution resulted in 18,000 deaths per year. This number was based on reports of the Dutch Environment and Nature Planning Bureau and the National Institute for Public Health and

Environmental Hygiene. Again, this worrying figure was the result of models computations. Below we will reflect on these numbers further.

2. *The more fashionable a scientific field is (with more scientific teams involved in the research area), the less likely the research findings are true (insight 3).*

   Science, as any other human endeavor, has its fads. With numerous research teams working on the same issues in a certain field and with immense experimental data being generated, timing is of the essence in defeating the competition. Thus, each team may prioritize on pursuing and disseminating its most impressive "positive" results.

   "Negative" results may become attractive for dissemination if some other team has found a "positive" association on the same question first. In that case, it may be attractive to refute a claim made in some respected journal. Consequently, rapidly alternating extreme research claims and markedly opposite refutations is indicative of this state of affairs, which is of great interest to the media as well. When such alternating extreme opposites of results and views from the scientific community are presented in the media, chances are that neither have any truth in them.

3. *The greater the the probability of the presence of nonobjective lower interests—caprice, prejudice, expectations, power, pride, wealth, fear—in a scientific field, the less likely the research findings are true (insight 3).*

   When opportunities to gather large sums of money are available within a certain academic field, the quality of research findings is bound to drop. Usually this is understood within commercial settings. Yet, the same holds true for research done by means of public funding.

   What often is forgotten is that governments have vested interests to push certain political agendas bolstered with scientific findings. Think for instance of the European REACH regulation (Registration, Evaluation, Authorization and Restriction of Chemicals). For more than a 100,000 chemicals, biological, chemical, physical, and toxicological data needs to be gathered and reported as a means to protect human health and the environment from the risks that can be posed by chemicals.

   We do not say anything new that chemophobia (prejudice, power, fear) is one of the nonepistemic drivers of REACH, as is made clear in the precursory "Strategy for a future Chemicals Policy" whitepaper of the European Commission in 2001 in which the "protection of human health and promotion of a nontoxic environment" is one of the key elements of REACH. As we have already seen, there is no such thing as a "nontoxic environment". Indeed, it is an incomprehensible term not conducive for life on earth, including our own.

   Incidentally, we should be wary of the genetic fallacy. This fallacy is committed when a proposition is accepted or rejected because of its origin, history, who speaks it, or who paid for it to be spoken. This fallacy is nothing other than an irregular and remote proxy of the actual content of the proposition. The latter should always be assessed on its own merits, and nothing else.

4. *The more reductionist and consensus-driven a scientific field is, the less likely the research findings are true (insight 1).*

When scientists within an academic field press for consensus around a certain cherished hypothesis, chances are that they try to block competing and tenable hypotheses for reasons other than the higher scientific interests. Consequently, chances are that research findings are less likely to be true. If the consensus hypothesis is strongly reductionist, whereby the scientistic fallacy looms large, things are aggravated. Although ignoring counterevidence in order to maintain the hypothesis under investigation is common, *forcing* consensus seems eccentric in the light of the well-documented fallibility of scientific understanding.

The late 19th-century luminiferous ether that postulated a medium (the ether) for the propagation of light is perhaps the most *famous* example of a generally accepted yet false scientific theory. It was invoked to explicate the ability of the wave-based light to propagate through empty (vacuous) space; something that waves should not be able to do. The most *infamous* scientific theory that was abandoned *and* repudiated is undoubtedly eugenics ("good origin"). This was the "science" of applying principles of genetics and heredity for the purpose of "improving" the human race and was a "settled science" by the end of the 19th century. It was seen as necessary for the preservation of society (Fig. 8.5).

FIGURE 8.5 Eugenics (Wellcome Library, London).

Investigators may suppress, for instance via the peer review process, the appearance and dissemination of findings that refute their own findings, perpetuating in their fields outdated or even false hypotheses and theories. The ousting of legitimate research that voice dissenting views is indicative of the fact that the truth content of research findings is under pressure.

Previously, we have discussed the linear nonthreshold (LNT) model and its faults, which are manifold. The consensus view in favor of the LNT still holds but it seems that more empirical views of dose−responses are finding their way in research and policy. Low and high doses differ in the responses they generate and are not linearly related by default. Assessing the extremes of exposure to generate the majority of the effects of exposure is the unnoticed fallacy the LNT harbors.

Reviewing all this, what are we to say about the menace in daily life and the ways in which this is researched and communicated? Some exposure to some substance might be said to "double the risk." But, if the *actual* risk goes from one in a billion to two in a billion, you only have an actual risk of two in a billion. Which is completely trivial. So, the *context* of actual risk—the doubling of one to two in a billion—is crucial in understanding what's going on. Rarely is such a context given.

Another issue is *practical* risk. If you have a high *actual* risk that only applies to a few people, the practical risk for the total population is still quite small. An extreme example will illustrate this: a risk of one in a million for 99 people (not exposed) is compared to a risk of 10 in a million for one person (exposed). We are talking here of a 10-fold increase in risk! Which sounds scary, no doubt. But the actual risk is still small for the total population of all 100 people within a population of a million.

A saner and less hyperbolic practice of science, one that is not quite so dictatorial and inflexible, one that is calmer and in less of a hurry, one that is far less sure of itself, one that has a proper appreciation of how much it doesn't know would benefit specialist and nonspecialist alike. However, there is much deserved and legitimate angst about the "reproducibility crisis" which afflicts those fields which (over-)rely on statistical methods. For instance, how do scientists tease out ever-smaller agent effects on our health as discussed in tool number 1? And is there any way to reproduce these results?

Actually, as we already discussed, observation is impossible here as any effect, if at all existent, is simply far too small to measure. Usually probabilistic (statistical) models play the dominant role. Probabilistic models are not causal, and can never lead to certainty. Probabilities (What are the chances that . . .?) are stand-ins for knowledge of causes; consequently these probabilities do not become and can never be causes themselves.

Nevertheless, these models are presented as to produce real-world public health information: 18,000 deaths because of PM air pollution in the Netherlands; 15,000−22,000 radon-related lung cancer deaths in the United

States. This in fact is the iniquity of reification, as we have seen before. This happens when models are regarded as real-world creatures. They are not. Reification happens, far too often, when we fail to recall that our mathematical creations are abstractions and not reality. And that rules out proper reproduction as real-world checks and balances are missing (Fig. 8.6).

One important reason why it is often thought probability models can discern cause is because of hidden bias. The bias is uncovered by thinking about who decides what goes into the databases as potential causes or proxies of causes. As Briggs explains: "Consider the proposition 'Bob spent $1124.52 on his credit card.' This 'effect' might have been caused by the sock colors of the residents of Perth, say, or the number of sucker sticks longer than 3 inches in the town of Gaylord, Michigan, or anything. These odd possibilities are not in databases of credit card charges, because database creators cannot imagine how these oddities are in any way causative of the effect of interest. Items which 'make the cut' are there because creators can imagine how these items are causes, or how they might facilitate or block other causes, and this is because the natures or essences of these items are known to some extent. ..." Consequently, the results are no more than the biases of the researchers they infused in their model *a priori*.

Another major issue is "control." Tributary "variables" are entered into models and are said to be "controls" like age, gender, weight, smoking, alcohol use, genetics, and so on. The attempt here is that the agent under scrutiny and its effects are "isolated" from all sorts of other agents

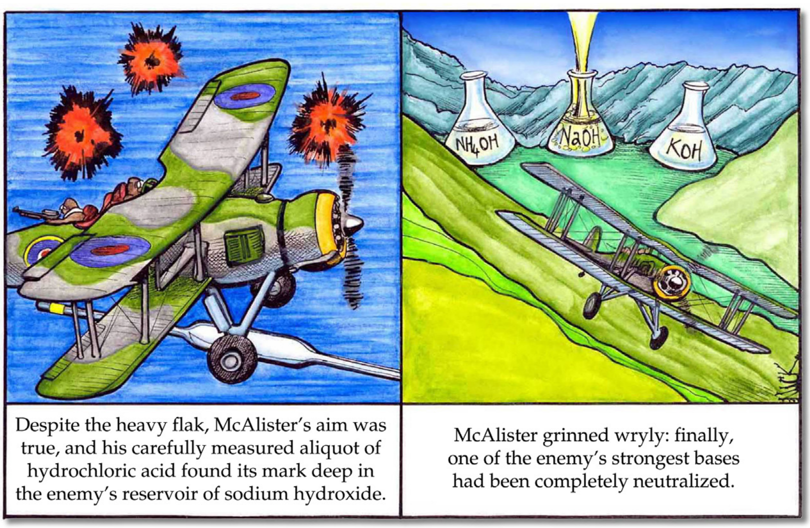

FIGURE 8.6 Reification cartoon (Nick D. Kim http://scienceandink.com/).

that might have similar effects as the one studied. The word "control" here is deceiving, and in fact a gross misnomer. Despite the many "controls" that can be infused into the model, there will always be other characteristics that are not or cannot be controlled for, because for instance they are unknown. The term "control" thus is the complete opposite of the truth of the matter.

Moreover, "controls" are usually (rough) proxies of actual causes. Take for instance gender. In athletic sports such as the 100 m, men gold medalists are faster than the fastest women. Does male sex as such cause the men to outrace feminine competitors? Far from it; gender does not determine that at all. Instead, gender causes differences in anatomy and physiology that are tied to differing athletic performance.

This is why the countless models that "control" for gender and which imply gender is "a cause" are always wrong (unless they are modeling direct effects of sex, such as pregnancy, and in which case, no model is used because we understand the essence). Gender is a proxy for (usually) multiple other causes and is itself not a cause. And this kind of reasoning also applies for things such as race, income, and education. Statistical models simply aren't capable of discerning cause.

So, is there any moral to the story of science, models, knowledge, and insights. We think there is. Perhaps the most important one is that any theory or model in science should be verified by making *predictions of observables* never (*as in never*) seen before. A good scientist, aware of at least the three (much repeated and straightforward) insights we have posited in this chapter, asks the pertinent questions, designs the experiments, collects the data in a transparent and accessible manner, builds the model, and then, every single time, this model must be used to make predictions. As the Dilbert-cartoonist Scott Adams proposed in his blog of the December 28, 2016 (much to the chagrin of a quite a few commentators):

> *So today's challenge is to find a working scientist or PhD in some climate-related field who will agree with the idea that the climate science models do a good job of predicting the future. ... Remind your scientist that as far as you know there has never been a multi-year, multi-variable, complicated model of any type that predicted anything with useful accuracy. Case in point: The experts and their models said Trump had no realistic chance of winning.*
>
> *Your scientist will fight like a cornered animal to conflate the credibility of the measurements and the basic science of CO_2 with the credibility of the projection models. Don't let that happen. Make your scientist tell you that complicated multi-variable projections models that span years are credible. Or not.*

This will help further the practice of science that is, more precisely should be, judicious and honestly self-critical. And it will help the citizens of this world. If predictions of certain pet theories of scientists go awry on an almost daily basis, forget about it. It's just fake news.

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