1.1 'The Republic of Science'

They say that when Charles D. Koch, the villain of the piece, was young, he studied philosophers like Aristotle, Descartes, and Marx. He certainly likes to think of himself as a thinker: he once introduced himself to a group of executives by saying, 'I am Charles Koch. I'm in the philosophy department.' But one particular piece of philosophy affected his thinking so profoundly that he incorporated its ideas into his fantastically successful business model. In his own words: 'What we try to model Koch Industries around is what a philosopher scientist Polanyi called "The Republic of Science".'[1]

Charles D. Koch with Head of a Philosopher

Michael Polanyi was a rare combination of gifted scientist and fine philosopher of science. He published 'The Republic of Science: Its Political and Economic Theory' in 1962, a short but rich essay on how the natural sciences operate and cooperate.[2] Since a great deal turns on what Koch and his fellow global warming deniers say about science and the climate, it's worth presenting the main points of Polanyi's account, for they also constitute a good introduction to the rest of this chapter.

Polanyi emphasises that science is a *cooperative* enterprise with a long tradition behind it. 'The first thing to make clear', he writes, 'is that scientists, freely making their own choice of problems and pursuing them in the light of their own personal judgment, are in fact cooperating as members of a closely knit organisation.'[3] And when you look into how this organisation is organised, it becomes more interesting.

> The activities of scientists are in fact coordinated, and the principle of their coordination ... consists in the adjustment of the efforts of each to the hitherto

> achieved results of the others. We may call this a coordination by mutual adjustment of independent initiatives.

Polanyi likens the organisation of scientists to the larger body politic—hence 'the Republic of Science'. But the remarkable thing about this organisation is that there's no organiser-in-chief: it's a republic without a president. Insofar as the discoveries of science are not 'premeditated', he characterises their coordination as being 'guided as by "an invisible hand" towards the joint discovery of a hidden system of things'—hence the 'Economic Theory' at the end of the essay's subtitle. It was presumably this allusion to markets and Adam Smith's 'invisible hand' that attracted Charles Koch, as a bitter foe of government and regulation, though we'll see that he misunderstands the point Polanyi is making here.

One reason the Republic of Science has no president is that even the most brilliant scientists are geniuses only in one field (or perhaps two): the domain of the natural sciences is so vast that no one person can possibly be expert across its entire range. But in most cases a competent scientist will be conversant enough with a field or two adjacent to her own to be able to assess the value of the work being done there. From there, imagine similar overlappings throughout the whole field:

> Scientific opinion is an opinion not held by any single human mind, but one which, split into thousands of fragments, is held by a multitude of individuals, each of whom endorses the other's opinion at secondhand, by relying on the consensual chains which link him to all the others through a sequence of overlapping neighbourhoods.

There *is*, then, an authority that reigns over the republic of science, but it's collective rather than individual.

And there *are* professional standards, 'standards of scientific merit accepted by the scientific community', which are in turn based, Polanyi shows, on generally accepted criteria. For a contribution to science to have scientific merit, it must have (1) 'a sufficient degree of plausibility' (which rules out contributions from 'cranks, frauds and bunglers'), in the sense that its methods and results must fit, more or less, with 'the current scientific opinion about the nature of things'. (2) It must have 'scientific value' in terms of its 'accuracy, systematic importance, and intrinsic interest' to the field. And (3) it must be 'original' in the sense that it produces results that are in some sense a surprise, or change the way scientists view the phenomena they study.

Whereas the first two criteria tend to enforce conformity, 'the value attached to originality encourages dissent'. If science didn't encourage originality it would stagnate, and Polanyi emphasises the constant tension between conservatism and innovation that drives the entire enterprise. Because scientists acknowledge that 'currently predominant beliefs about

the nature of things' that ground 'the authority of scientific opinion' are subject to change over time, they encourage the younger generation to challenge the orthodoxy. 'Scientific tradition enforces its teachings in general, for the very purpose of cultivating their subversion in the particular.'

In a rare interview he granted in 2016, Charles Koch mentioned 'the republic of science' no fewer than twenty-three times in the course of a hundred minutes.[4] After denying human-caused climate change for decades, he also made this revelation: 'Yeah I believe it's been warming and I believe that the evidence is there are such a thing as greenhouse gases, and they're contributing to that.' But then comes the *but*: 'But I don't think anybody knows how much. I don't think science is settled. I mean how could it be? … As a matter of fact, science is never settled.'[5] That last point is right too: science is never settled—Polanyi says just that. The capacity of natural science 'to renew itself' and keep on discovering comes from its practice of 'evoking and assimilating opposition to itself', its tendency continually to unsettle itself.[6]

It's true that climate scientists don't know exactly how much human activity rather than natural variation is responsible for the current warming, but they know enough to know that the climate will create intolerable conditions in many parts of the world if we keep on warming the atmosphere. And now the crux, when the interviewer posed this pointed question: 'Could someone produce a piece of research that could convince you that carbon regulation is necessary to head off disastrous global warming?' Koch responded by invoking Polanyi's idea:

> If we apply the Republic of Science here and use the scientific method rather than of trying to shut down and shout down and punish anybody who wants to enter into debate about it. … I'm all for applying the Republic of Science on climate, as I am on anything.

If you apply Polanyi's idea to the climate sciences, you find several thousand experts working together in 'coordination by mutual adjustment of independent initiatives'. In 2011 some 99% of them were persuaded by the evidence that human activities are contributing to global warming. Thanks to the interference of the Koch Brothers and their billionaire colleagues that figure went down to 97% over the next eighteen years, until in 2019 it came back up to 99.[7]

Innovation in this field is largely a matter of explaining some aspect of the climate system that has been poorly understood. None among the dissenting one per cent of scientists has done research showing that carbon dioxide isn't a greenhouse gas after all, or anything approaching such a revelation. In fact they hardly conduct any research of their own, preferring

to cherry-pick other scientists' data for anomalies that (they argue) undermine the research results. Polanyi isn't saying that 'anybody who wants to enter into debate about it' must be listened to: rather, to be taken seriously you have to be *in* the republic of science and working under 'the authority of scientific opinion'. But the cranks in the think tanks that the Koch Brothers have been funding for decades are beyond the pale because they simply dismiss that authority.

Charles Koch doesn't get this because he's fighting a war of ideas, and so dismisses scientific expertise when he has to. As someone in the business of buying and selling, he misunderstands Polanyi's allusion to the invisible hand to mean that scientific opinion should be subject to market forces. He thus draws the convenient conclusion that whoever dispenses enough cash, or else is being handsomely paid, should be listened to respectfully by the scientists.

Koch plays up Polanyi's acknowledgment that 'scientific opinion may, of course, sometimes be mistaken, and as a result unorthodox work of high originality and merit may be discouraged or altogether suppressed for a time.' This is his pretext for funding mediocre scientists who will come up with the results he wants to see—burning fossil fuels isn't contributing to global warming—and whose interventions are justly dismissed by the experts.

And this is precisely Polanyi's point: he insists that standards must be strictly enforced, even if the occasional mistake is made, because 'Only the discipline imposed by an effective scientific opinion can prevent the adulteration of science by cranks and dabblers.' He emphasises the importance of safeguarding the autonomy of the scientific enterprise and rejecting 'the interference of political or religious authorities'. That's why you need robust professional standards. Otherwise, 'Politics and business play havoc with appointments and the granting of subsidies for research; journals are made unreadable by including much trash.' Koch's enchantment by the invisible hand blinds him to these implied indictments of business's financial meddling in the Republic of Science. Polanyi is *not* saying that the Republic of Science should be ruled by economics and the free market: rather the opposite—that financial considerations should be kept out of it altogether.

If Koch's sense of how science in general works is so distorted, he can hardly be expected to appreciate the status and function of the climate sciences in particular. They form a special field within the Republic of Science, an area where the atmospheric and ocean sciences overlap with physical geography and other sub-fields of chemistry and biology, and they emerged under the Monarchy of the Habsburgs. Let me conclude these

reflections on the Republic of Science with a few paragraphs on the Climate of Empire.

Climatology was developed as a science in the mid-nineteenth century, and in the vanguard was a group of scientists in the Austro-Hungarian Empire who were in the employ of the Habsburg aristocracy. Various meteorological institutes were founded around this time, but what distinguished the work of the Austrian scientists was their dual focus on local weather conditions *and* climatic conditions on a large scale. The epigraph to Deborah Coen's first-rate history of the Viennese School of climatology is a saying attributed to Francis I, first emperor of Austria: 'There is no affair that a priori and according to general principles could be called large or small; matters are only large or small in comparison to and in relation to other things.'[8]

It was in Vienna, not far from where I'm writing these words, that the oldest weather service in the world began operations in 1851, the Royal-Imperial Central Institute for Meteorology and Geomagnetism (later Geodynamics).[9] This institute became the centre of a vast network of scientists and weather stations and observatories throughout the Austro-Hungarian empire. Just as the Habsburg monarchy's maxim was 'unity in diversity', insofar as its various peoples and cultures were supposed to retain their particular characters, so the vast range of sub-climates throughout the Empire were to be understood in terms of the larger whole.

The founding director of the Central Institute in Vienna was the astronomer and meteorologist Karl Kreil. In the opening pages of his path-breaking book *The Climatology of Bohemia* (1865), Kreil emphasised the importance of investigating *interactions* between 'large-scale atmospheric processes and the organic or inorganic surface of the earth', and especially across different scales in space or time. On this topic he was in agreement with the great Alexander von Humboldt, with whom he corresponded.. 'There is everywhere a macrocosm and a microcosm,' Kreil wrote, 'a world on the large scale and the small—the latter just as important, often more so, than the former.'[10]

The Central Institute's third director was Julius Hann, 'founder of modern climatology', who amplified the scope and spirit of Kreil's achievements.[11] One of Hann's major contributions—as suggested by the title of his influential book, *The Earth as a Whole: Its Atmosphere and Hydrosphere* (1872)—was a holistic understanding of atmospheric phenomena: the idea that local conditions are ultimately a function of the entire climate system. Coen shows how the Habsburg scientists introduced the key idea of *scaling* into climatology: 'They insisted that nature could not

be measured solely according to a scale derived from human concerns; other measures of significance were needed when studying nature on the very small scale or the very large.'[12]

By careful and painstaking recording of small-scale conditions at thousands of locations throughout the varied topography of the vast empire, members of the Viennese School were able to extrapolate and model the data for larger units, and ultimately—thanks to temporal scaling as well—for the geosphere as a whole. By going beyond the narrow, anthropocentric perspective of the natural sciences of their time, they initiated the development of modern climatology.

Their interest in scaling was grounded in the natural philosophy of their predecessors in the Renaissance, and in figures like Paracelsus, Tycho Brahe and Johannes Kepler. Working in a world that made no division between astronomy and astrology, it was natural for those earlier thinkers to assume influences of the macrocosm on the microcosm—of the earth (and other heavenly bodies) on the human body, for example. Along with their insistence on detailed empirical investigation, the Habsburg scientists retained a sense for ancient notions of the 'world soul' and an animate earth, continuity between organic and inorganic, resonances between microcosm and macrocosm, relativities of size and scale, and various affinities between heaven and earth and the human body.

What's interesting here is that whereas these guiding ideas have more or less disappeared from modern climate science, they were central to ancient Chinese ways of thinking and continue to inform contemporary Chinese thought (as we'll see in Part Four).

The global warming deniers are incapable of appreciating the sophisticated complexity of the relevant sciences, which allow practitioners to understand the behaviour of the whole earth system so as to be able to predict (to some extent) what's going to happen on the ground and in the air and sea. And now, with the help of palaeoclimatology and computer modelling, they can reconstruct what conditions were like long ago, as well as imagine what they'll be like in the near future.

1.2 Objections and Responses

Since most people have some sense that global warming is happening, let me outline the situation by responding to some of the most frequently heard objections to the findings of the climates sciences concerning the human contribution to climate change.

No Certainty!

Climate sceptics have been saying for decades that the scientific evidence for human-caused global warming isn't yet sufficient to warrant *certainty*. Politicians love to hear this, since it allows them in turn to say (as George W. Bush said throughout his presidency): 'We need to *wait* until the science of global warming is certain.' This is nonsense, because certainty is not always attainable in the natural sciences, and only rarely in the climate sciences. A basic principle of quantum mechanics is called the Uncertainty Principle for good reason: Werner Heisenberg showed that, in the realm of subatomic particles, the more certain we become about a particle's position, the less certain we can be about its momentum—and vice versa.

As the contemporary physicist Carlo Rovelli has observed, 'Science Is Not About Certainty'. Arguing that science is concerned with improving 'the conceptual structure we use to grasp reality', he writes:

> Science is about finding the most reliable way of thinking at the present level of knowledge. Science is extremely reliable; it's not certain. In fact, not only is it not certain, but it's the lack of certainty that grounds it. Scientific ideas are credible not because they are sure but because they're the ones that have survived all the possible past critiques, and they're the most credible because they were put on the table for everybody's criticism.[13]

As the great philosopher of science Karl Popper insisted, for a hypothesis or theory to be considered scientific, it must be *falsifiable*.[14]

Whereas we can be certain that the boiling point of water (at sea level) is 100°C because this has been tested innumerable times in various places and never refuted, disciplines like meteorology, oceanography and climatology aren't in a position to perform laboratory experiments to test their hypotheses. The laboratory would have to be the entire biosphere, where too many variables abound to permit controlled experiments.

Instead the climate sciences use statistics to calculate probabilities, and employ computer modelling to try to understand and predict patterns of climatic change. But the uncertainty that pervades the climates sciences doesn't mean that we don't understand a great deal about how the climate works – and we understand better with every passing year.

When considering what action to take in the face of uncertainty, scientists often recommend following the 'Precautionary Principle'. This says that, in situations where scientific evidence gives us good reason to suppose that certain activities will prove harmful in the long run, the burden of proof should lie with those proposing to undertake such activities, and that action should be taken to prevent or minimise harm even when the scientific evidence doesn't provide full certainty. At the UN 'Earth Summit' in 1992, representatives from 194 nations agreed that, 'In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities'.[15] Sadly, this

agreement seems to have been ignored by most of the parties who signed up to it.

Reports by the IPCC deal with the problem of uncertainty by specifying the level of confidence derivable from the scientific evidence using five 'qualifiers', from 'exceptionally unlikely' to 'virtually certain'.[16] So, to say that we should wait because the science isn't yet certain is to miss the point completely. It would be like waiting for Godot, except even more futile—and in the face of stakes that could hardly be higher.

Correlation and Causation

In 2010, when I was teaching in Ireland, I went to Dublin to attend a public lecture given by the Nobel Prize-winning atmospheric chemist Paul Crutzen at Trinity College. His title was 'The Anthropocene: A New Geological Epoch Dominated by Human Activities'. A decade earlier, Crutzen and Eugene Stoermer had coined the term 'anthropocene' to designate a new geological epoch in which human activities have a lasting impact on the earth's ecosystems. After an overview of the many, mostly destructive, ways in which human activities have affected the geosphere, they reported that research indicates that 'because of the anthropogenic emissions of CO_2, climate may depart significantly from natural behaviour over the next 50,000 years.'

Another way of putting this would be to say that the activities of the past eight or so generations of human beings will have an impact, mostly destructive, on the lives of the next *two thousand* generations—in the unlikely event that the human race lasts that long. That's a proposition worth pondering. Crutzen's lecture at Trinity College was an erudite amplification of these considerations, supported by slides of graphs and charts that presented the relevant data in depressing detail.

The first person to speak in the question-and-answer session trotted out this old canard, still to be found on the front pages of global warming-denying websites: 'Just because there's a *correlation* between more CO_2 in the atmosphere and higher temperatures doesn't mean that the CO_2 is *causing* the warming. Correlation doesn't imply causation.' The second sentence is true, but irrelevant. It was hard to tell, from where I was sitting, whether the expression on Crutzen's face was one of resignation, exasperation, sorrow over the depth of human stupidity, or a combination of all three. In any case, after a short pause, he simply sighed, and called on the next person with a hand up.

My first thought about the questioner was, 'Doesn't this jerk know that Crutzen won the Nobel Prize for his work in atmospheric chemistry?' The poor man (Crutzen) must have heard this 'correlation doesn't imply causation' homily so often that he's given up trying to respond to it. As a

good scientist he understands the distinction between correlation and causation, but he can hardly be expected to rehearse it every time for the benefit of those who don't. Then I was afraid that some people in the audience might be thinking that Crutzen didn't actually *have* a response to this superfluous comment, and that perhaps global warming was after all merely correlated with, and not caused by, increased concentrations of atmospheric CO_2.

The concept of causality is more complicated than you might think. We non-scientists tend to take examples from Newtonian physics as the paradigm, where a single cause brings about a single effect. The impact of the white billiard ball causes the red one to roll across the baize and into the corner pocket. But events in nature are rarely that simple: a phenomenon usually comes about owing to multiple causes in dynamic interaction, as when a tropical storm results from a confluence of many different weather conditions. It's rarely a matter of effect E being caused by cause C, but more often of E's happening as a result of conditions B, C, D, F, G, H, et cetera.

(This idea fits well with understandings of causation in ancient Chinese science, which assume that everything is ultimately interacting with everything else. Similarly with Buddhism and its teaching of 'interdependent arising': when any phenomenon comes into being, it's under these particular conditions, and when it ceases to be, it's under those other particular conditions.)

The causality behind thorny questions in epidemiology and public health is usually of this nature. Although we may determine that the presence of a particular bacterium in the water supply is causing a certain disease, it's very hard to prove that industrial chemicals being discharged into a river are causing leukaemia and cancers in the local population. This is because many other factors may be contributing.

The situation is similar with cigarette smoking and lung cancer—a fact that enabled the tobacco companies to deny that smoking *causes* cancer, on the grounds that many smokers don't get lung cancer and some non-smokers do. Strictly speaking we can only say that there's a causal connection of this kind: the greater the number of cigarettes you smoke, the greater the risk that you'll develop the disease. It's a matter of probabilities and the significance of statistical outcomes. We may nonetheless say that, since the evidence is so overwhelming, we can regard the connection as 'deemed proven'.[17]

In the case of the climate sciences, we can say that scientists have understood the causality behind the 'greenhouse effect' for almost two centuries: certain gases in the atmosphere trap heat that has come in from the sun and bounced off the earth's surface, preventing some of it from

radiating back into space. It was the French mathematician and physicist Joseph Fourier who first drew attention to what we now call the 'natural greenhouse effect'. In a paper published in 1827 he wrote:

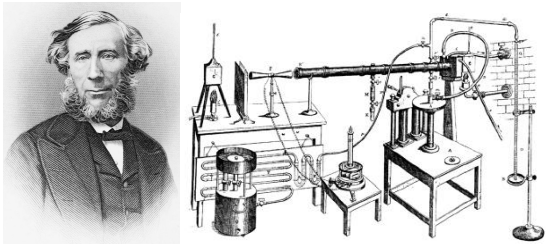
> The temperature on the earth is increased by the presence of the atmosphere, because heat in the form of sunlight encounters less obstruction when coming in through the air than when it passes back through the air after being converted into [infrared radiation].[18]

If it weren't for the atmosphere, temperatures on earth would be some 33°C cooler than they actually are—far too cold for life on earth.

The Irishman John Tyndall later put the same point more poetically, emphasising the role of water vapour:

> This aqueous vapour is a blanket more necessary to the vegetable life of England than clothing is to man. Remove for a single summer night the aqueous vapour from the air that overspreads this country, and you would assuredly destroy every plant capable of being destroyed by a freezing temperature. The warmth of our fields and gardens would pour itself unrequited into space, and the sun would rise upon an island held fast in the iron grip of frost.[19]

It was Tyndall who discovered, in 1859, the physical processes behind the greenhouse effect with the help of an instrument he designed and constructed himself, the world's first ratio spectrophotometer.



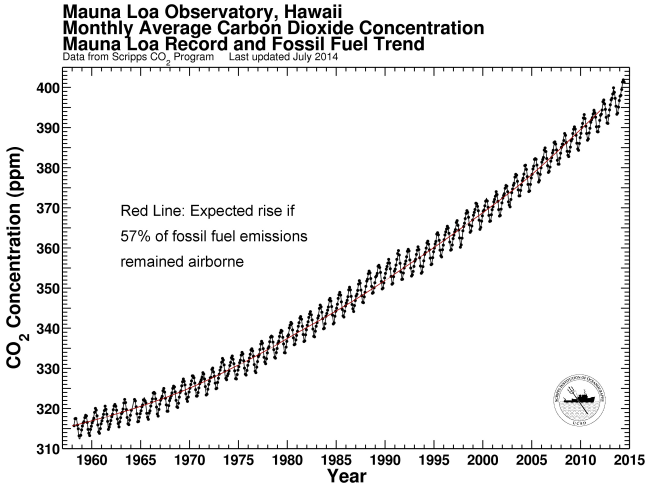
John Tyndall and his ratio spectrophotometer [20]

This magnificent device allowed Tyndall to perform experiments on the ways various gases absorb and transmit solar radiation. He discovered that, while the nitrogen and oxygen that make up most of the surrounding air have almost no effect on radiant heat, the water vapour, carbon dioxide and methane in the atmosphere absorb, trap and reflect heat back. Heat-trapping gases are distinguished by their selectively absorptive properties, being transparent to the visible, short-wavelength, heat-imparting light of the sun's incoming radiation, but partially blocking and re-radiating the infrared, long-wavelength radiation that's reflected back from the surface of the earth.

Tyndall anticipated recent discoveries in paleoclimatology when he speculated that changes in concentrations of greenhouse gases could have produced 'all the mutations of climate which the researches of geologists reveal. … They constitute true causes, the extent alone of the operation

remaining doubtful.'[21] So there's not merely a correlation between more CO_2 in the atmosphere and higher temperatures: we now *know* that emissions of greenhouse gases like carbon dioxide trap heat in the atmosphere and are thus 'true causes' of global warming (even though 'the extent of their operations' can't be precisely determined).

Here's a chart showing the correlation between the steady rise in concentrations of atmospheric CO_2 over the past fifty years and the increase in industrial emissions of CO_2 from fossil fuel combustion and cement production over the same period.[22] (Land-use change and deforestation are thought to contribute between 4 and 14 per cent.[23] *Update) We know that almost half the CO_2 we emit is absorbed by trees and other vegetation in spring and summer, as well as by the world's oceans. And if we assume that 57% of fossil-fuel emissions remain airborne, we get a perfect fit between the emissions curve and the CO_2 levels. As long as you take factors of natural variation into account, this correlation confirms that the increasing levels of CO_2 are mainly a result of human activities.



Fossil fuel emissions and concentrations of CO2

The carbon dioxide we've been spewing into the atmosphere in ever-increasing amounts since the Industrial Revolution isn't just affecting the climate in *our* generation, but will affect it for many generations to come. Recent research suggests that Crutzen and Stoermer weren't exaggerating this point. It's hard to tell just how long the gases we're emitting stay up there: scientists used to say that atmospheric CO_2 persists for a century or so, but we now know it can last a lot longer than that.

David Archer, a professor of geophysical sciences at the University of Chicago, announces at the beginning of his book *The Long Thaw: How Humans Are Changing the Next 100,000 Years of Earth's Climate* the following sobering news: 'The lifetime of fossil fuel CO_2 in the atmosphere is a few centuries, plus 25% that *lasts essentially forever*. The next time you fill your tank, reflect upon this.'[24] But most people in the US (and other

places) don't reflect on such things; many keep on driving their huge SUVs and assume that the costs will fall to other people to pay.

Even if we were to stop emitting carbon immediately, tomorrow, which is impossible, the inertia in the climate system ensures that the temperature will rise some by some 0.6°C over the course of the 21st century. The oceans absorb much of the excess heat, but some greenhouse gases stay up there for a long time. According to an IPCC report from 2013, 'Aerosols have a lifetime of weeks, methane (CH_4) of about 10 years, nitrous oxide (N_2O) of about 100 years and hexafluoroethane (C_2F_6) of about 10,000 years.' The situation is more complex with carbon dioxide, because of its interactions with vegetation and the oceans, but while around half the volume of an 'emission pulse' typically lasts 'a few decades', around a third will still be 'in the atmosphere after 1000 years'. This is why the effect of stopping GHG emissions isn't immediate.

> Methane concentration would return to values close to pre-industrial level in about 50 years, N_2O concentrations would need several centuries, while CO_2 would essentially never come back to its pre-industrial level on time scales relevant for our society.[25]

The changes we're wreaking on the atmosphere are virtually irreversible—but since they're so obviously damaging now and in the short term, why not try to minimise them?

The 'Natural Variation' Objection

Along with the steady rise of greenhouse gas emissions and concentrations of CO_2 in the atmosphere there has been a steady rise in average world temperatures. As of this writing, the last five years 2014 to 2018 were the hottest ever recorded since comprehensive measurements began 150 years ago.[26] Concentrations of atmospheric carbon dioxide are also hitting record levels: the last time they were this high, according to the paleoclimatological record, was some 3 to 5 million years ago. In May 2019 the concentration reached a record since the beginning of human history: 415 parts per million.[27]

But wait! say the sceptics: the temperature rise could be a result of *natural variation* rather than human activities. Well, that possibility shouldn't be ruled out, since the climate system is extremely complex; but the objection assumes that the climate scientists haven't already contemplated the possibility—and ignores the fact that it's they who discovered natural variation in the first place and haven't forgotten about it since.

Paleoclimatology, a fascinating branch of science that studies the climate in ancient times, has shown that there can indeed be substantial natural variations in the world's climate. The most impressive are the long-term

swings between 'Snowball Earth', when the planet is covered with ice, and 'Hothouse Earth', when the earth is completely ice-free.[28] Several different factors called 'climate forcings' affect this process, the basic one being variation in solar output, which determines the amount of solar energy coming in to the geosphere. Then there are changes in the axial tilt of the earth, the 'precession' (wobble) in its spin, and the shape of its orbit, which isn't quite circular. All these affect a place's relations with the sun, and hence its climate.

On the earth itself, the greatest, though slowest, force is the movement of the tectonic plates that compose the lithosphere (the crust and upper mantle of the earth; from the Greek *lithos*, meaning 'stone'). These movements, over several billion years, have made and unmade oceans, thereby changing the climate massively—but very, very slowly. The oceans on top of the plates undergo extensive changes in temperature and currents, which are caused by a number of different 'oscillations' (the El Niño/Southern, North Atlantic, Pacific Decadal, etc.), and by 'thermohaline' circulation (the 'ocean circulation conveyor belt'), whereby warm and shallow and cold and deep currents circulate between the Atlantic and Pacific oceans.

Another climate forcing comes from volcanic activity: massive eruptions occur seldom, but have powerful short-term effects. The particulates emitted by a volcanic eruption spread around the atmosphere and block incoming solar radiation, thereby letting the air below cool down. After the eruption of Mount Pinatubo in 1991, for example, average global temperatures decreased by 0.5°C over the following two years.

Climate scientists are fully aware of these natural variations and factor them in to their climate models. Their understanding of how the climate works is admittedly incomplete, but by 2013 two independent studies demonstrated a consensus among some 97% of researchers in the field that human activity is a major contributor to global warming. One of them reviewed 1372 articles in the scientific literature and found in addition that 'the relative climate expertise and scientific prominence of the researchers unconvinced of anthropogenic climate change are substantially below that of the convinced researchers'.[29] So, the few dissenters are distinctly less expert—and perhaps inclined to being contrary as a way of compensating for their lack of scientific competence.

Although natural scientists can be contentious types, they tend to be very cautious about issuing bold public statements. On top of that, the best climate scientists are usually specialists, and so are reluctant to speak out about the general situation. (The former NASA scientist James Hansen is a salient exception.) Professional organisations of scientists are even more

cautious than their individual members. They have an enormous stake in upholding their reputations, and so take great pains to avoid saying anything that could possibly turn out to make them look stupid. Nevertheless, by 2009 no fewer than 197 scientific organisations worldwide had publicly endorsed the proposition that 'climate change has been caused by human action'.[30]

Anyone who remains sceptical in the face of this overwhelming consensus is advised to consult the latest in the series of reports since 1990 by the IPCC—*Global Warming of 1.5°C*, mentioned earlier—as well as the 'Synthesis Report' from *Climate Change 2014*, which synthesises the results of the three comprehensive reports published that year. The principal documents are long (several thousand pages in total) and sometimes very technical, but there are two very readable accounts of them by accomplished climate scientists.[31]

The 'Fallible and Biased' Objection

'But the IPCC has made *mistakes*!' the sceptics cry. 'They're *biased*! The UN is out to destroy the American way of life!' It's true that the thousands of contributory authors, reviewers and consultants who contribute to the IPCC's reports (and receive no pay for their labours) are human, and therefore fallible. But the occasional errors that find their way into the reports are negligible by comparison with the enormous amount of responsible research the IPCC has synthesised over the past 25 years and the huge number of experts that collaborate on their projects.[32]

To accuse the IPCC of bias is simply absurd. For example, the 'core writing team' for the 2014 Synthesis Report (a document of only 150 pages) comprised experts from 24 different countries, including China, Cuba, India, Korea, Malaysia, Mali, and Mexico, as well as the American and European countries one would expect. A few snippets from the Preface to a significant report by the IPCC, *Renewable Energy Sources and Climate Mitigation* (2011), give a sense of the organisation's methodology: the study was carried out by 'an author team of 122 Lead Authors (33 from developing countries, 4 from economies-in-transition countries, and 85 from industrialized countries), 25 Review Editors and 132 contributing authors'. The IPCC procedure requires two different reviews of drafts produced by the authors, in the course of which '24,766 comments from more than 350 expert reviewers and governments and international organizations were processed'.[33]

As mentioned earlier, the IPCC is an inter*governmental* panel, which means that politicians from well over a hundred countries have input into the final reports. This is hardly a situation that encourages bias—and many

climate scientists complain that the political elements make the reports too *conservative*.

Another reason the sceptics accuse the climate scientists of bias is because 'they're in it for the money'. But most natural scientists work for universities and government institutes, where their salaries are generally lower than for comparable positions in the private sector. Yes, they often get paid through large grants from government science foundations, but that's usually *instead of* rather than in addition to their university salaries. Sceptics seem impressed by the large amounts of money attached to government grants, but these amounts are for research assistants, equipment, institutional overheads, and so forth, and don't enrich the grantees personally.

For all the decades of far-right complaints about scientists getting paid (more) to come up with results that confirm global warming, the complainers have yet to produce a single instance where a government or university science grant is dependent upon the researchers coming up with results approved of in advance by the granting agency.[34] The only scientists I know of who get paid for certain kinds of results (we'll meet some in Chapters 3 and 4) are employed by think tanks and institutes funded by global warming deniers. There are also some independent contrarians who have turned global warming denial into a source of income. Having had first hand experience of one of their number, I'll recount something of the encounter in the following section because it reveals the tactics of another band of fighters in this war of ideas.

But this list of objections wouldn't be complete without the most naïve and simplistic one: Winters are getting *colder*—so the scientists must be wrong about the warming! In response to reports that '2014 had been the warmest year on record', Senator James Inhofe lobbed a snowball to the Chair of a Senate committee, saying 'It's very, very cold out, very unseasonable'.[35] He was roundly ridiculed—and justifiably, since he was Chair of the Senate's Environment Committee at the time—for failing to understand the difference between weather and climate.

An increase in average global temperatures can be accompanied by episodes of extreme cold in winter: it's what has actually been happening. Scientists think this occurs (in the northern hemisphere at least, and especially in the north-eastern US) because a warmer Arctic leads to swings in the jet stream that brings colder air to places farther south.[36] But the ignoramus deniers continue to trot out this tired canard, confident perhaps that their audience won't know better. After a cold snap in November 2018, Trump tweeted: 'Brutal and Extended Cold Blast could shatter ALL RECORDS – Whatever happened to Global Warming?'[37]

1.3 Confronting Monckton

One day in the autumn of 2010, when I was teaching at University College Cork in Ireland, I received an 'urgent' email message from the president of the Debating Society. They've invited Lord Christopher Monckton to a debate on the proposition 'Man-made Global Warming is a Global Crisis', and the person from the University who was going to speak in favour of the motion, against Lord Monckton, has just fallen ill. Would I be willing to save the Society the embarrassment of cancelling the event, and step in to propose the motion? And sorry it's such short notice: the debate is next Tuesday evening. In five days.

So who was this Lord Monckton? I recalled reading something about him, but couldn't remember what or where. Checking on Wikipedia, I discovered that he's 'a British public speaker and hereditary peer'. Perhaps the person I was being asked to replace had fallen ill from panic and anxiety. Christopher Monckton was an orator with considerable experience: not only had he been touring the world for several years denying global warming, but he had also testified before the US Congress on several occasions (at the invitation of the Republicans). And I hadn't taken part in a debate since I was a schoolboy. But at least it turned out that Monckton wasn't a member of the House of Lords after all, which made him seem like a bit of a pretender.

I debated for a while. Only five days to pull a speech together, and I had three classes to teach in the meantime. On the other hand I'd been studying the climate sciences for long enough to know that the claims about climate change that I found Monckton was making were specious. And yet, I would be up against a seasoned public speaker and wasn't myself well versed in the arts of persuasion.

When we're evaluating the validity of what people are telling us, it's always a good idea to follow the money. Monckton is in some respects brilliant but has no qualifications or training in natural science. Since his assertions about global warming contradict the 97% consensus among the experts, why would anyone invite him to talk about what's really happening with the climate. His income from public speaking *depends* on his being contrarian. It's true that *I* don't have any qualifications in the climate sciences either, but at least I've studied the extensive literature impartially, without any personal or financial stake in the answer to the question of whether global warming is being caused by human activity. Personally, I wish it weren't human-caused, but unfortunately it is.

Either Monckton is an arrogant ignoramus who believes he understands the climate sciences when he doesn't, or he's cynically disseminating what

he knows are falsehoods for the sake of money and the adulation of the gullible rich. (It apparently costs up to £25,000 a speech if you book him through the 'Parliament Speakers' website.[38]) On top of that, much of his reported speech sounded abusive and bullying. But whatever his motivation, the man is a public menace, someone whose activism was obstructing progress on slowing global warming and thereby increasing human suffering. I wrote back to the Debating Society saying I'd give it a try.

After a couple of days of trying to pull something together, I was beginning to regret that decision. But then came a lucky break: I remembered where I'd seen that name before. It was in an article in *The Guardian* reporting on a refutation by twenty-one prominent climate scientists of claims Monckton had made while testifying to a US congressional hearing earlier in the year.[39] Under the title 'Climate Scientists Respond', experts in the fields Monckton had encroached on refute the main points of his testimony under nine separate headings: first an assertion by Monckton, and then its refutation by several expert scientists. This document made my task much easier, although Monckton's petulant rejection of it as a 'prolix, turgid, repetitive, erroneous and inadequate response to my testimony' suggested that *whatever* I said, it wouldn't make much of an impression.[40]

On the evening of the debate, the organisers introduced us: Monckton was impressively tall and expensively dressed. We greeted one another cordially enough. But when in the course of my opening speech I introduced a publication with the title 'Climate Scientists Respond', I noticed a distinct darkening of his previously beaming countenance. He apparently wasn't expecting a philosophy professor at some Irish university to have come across the devastating refutation of his testimony to Congress.

I made it clear that the responding climate scientists (for example: David Archer, James Hansen, Lee Kump, Michael MacCracken, Michael Mann) are all distinguished experts in their fields, and summarised their demolition of Monckton's testimony. I reported their calling his assertions 'extremely superficial' and 'profoundly wrong', insofar as they 'totally misinterpret the physics'. His arguments, they said, are based on premises that are 'simply false', contain 'reasoning and calculation that is simply incorrect' and numerous statements that are 'misleading', making frequent 'illogical leaps'. After rejecting his testimony as utterly bogus, the responding climate scientists warned that nonetheless, 'for those having little or no acquaintance with climate science, Monckton's assertions may sound scientifically credible'.

Monckton was not amused by my account of how the real scientists had demolished his credibility, but when he took the floor he spoke persuasively, without any notes. It was an impressive performance in form, if not in content. Because its most remarkable feature was his failure to respond to *a single one* of the points I had just made, aside from a brusque dismissal of the climate scientists' refutation as 'simply false'. He just launched into what sounded like his usual, well rehearsed spiel, repeating many of the assertions, and trotting out the same cherry-picked figures, that were in his testimony to Congress! But since the audience had just heard an account of the experts' debunking of his claims, I suspect that Monckton himself realised they weren't having the usual effect. There was a sense of protestations going limp, not quite enough wind in the sails.

As he finished his speech, brimming with confident positivity yet sounding a little hollow, the posturing came across as pathetic. The result of the debate: only one person voted against the motion (for Monckton)—a rout, and rare defeat, I'm sure, for my worthy opponent. There were flashes of dark in his look; but at least he was well paid for his efforts.

When the students took us out to the pub afterward, I was relieved that Monckton showed no interest in any further conversation. When he took his leave we shook hands, and I asked him where he was off to next. China, he said. Oh really? I have a great interest in China myself. Bon voyage!

As I watched him go, I wondered whether he would ever stop. It's characteristic of global warming deniers that they just can't give up. Some of them may have started out sincerely believing what they were saying, but then they have to realise that the evidence against them has been piling up. Better of course to say 'I now realise I was wrong' sooner rather than later, because the longer you wait, the greater the eventual disgrace. But as long as peddling falsehoods remains profitable, they continue to deny.

Monckton certainly continued—thanks to generous support from the richest person in Australia, the mining magnate Gina Rinehart, who co-sponsored another speaking tour of Australia for him after his trip to China.[41] She plays the same game as Rupert Murdoch, using her substantial stakes in Australian media to persuade people that human activity isn't contributing to global warming. Some years after the Monckton gigs, her company Hancock Prospecting donated some $4.5 million to the Institute of Public Affairs, an Australian think tank that promotes denial of human-caused global warming.[42] Aided by poseurs like Monckton, Rinehart has managed to sabotage Australia's efforts to deal with climate change.[43]

I've recounted my experience with Monckton because it's emblematic of several themes in the first part of the book. The obstructions to progress on global warming are based in denial, and denial is contagious: it's easily

spread, and most effectively by clever people who can appear to know the science. The business of disseminating doubt about the human contribution is unusually lucrative. People will pay good money to have someone assure them they're justified in their hopeful fantasies, and so don't have to bother to change their views or behaviour.

Global warming deniers and their sponsors like to portray themselves as victims. They complain that bold contrarian thinkers like Monckton and courageous disruptive 'climate scientists' (like those we'll meet in Chapter 4) are being unfairly shouted down by the majority of scientists for contradicting orthodox scientific opinion. Recall Koch's objection to those 'trying to shut down and shout down anybody who wants to enter into debate about it'.[44] But here's what Koch, given his admiration for Polanyi's ideas, *should* say about Monckton: without the knowledge and understanding required for membership of the scientific community, he simply lacks the qualifications for entering into scientific debate. In any case he never even tries to engage his opponents in dialogue, preferring to simply dismiss them as *wrong*. And when this is pointed out, he just goes on doing it, louder and more positively than before. No wonder so many people call him a bully.

To avoid ending the chapter with such an unsavoury character, let's turn to the perfect antagonist to 'the lord of climate denial', the climate scientist James Hansen, 'the father of climate change awareness'. In an interview on the last day of the Paris climate conference in 2015, Hansen dismissed the event as 'a fraud': 'It's just worthless words. There is no action, just promises.' Lamenting the fact that the frontrunners for the Republican presidential nomination for 2016 were all global warming deniers, Hansen nailed it nicely: 'It's all embarrassing really. After a while you realise as a scientist that politicians don't act rationally.' His pessimism was justified: we ended up with Trump and his cronies.

But the interview ended on a positive note, when Hansen said that he 'believes China, the world's largest emitter, will now step up to provide the leadership lacking from the US'. The man has been proved right in most of his forecasts concerning climate change, and I hope he's right about this crucial issue in geopolitics too. In a rare access of optimism he added: 'I think we will get there because China is rational. Their leaders are mostly trained in engineering and such things, they don't deny climate change, and they have a huge incentive, which is air pollution. ... *But they will need cooperation*.'[45] I've added emphasis to that last sentence because it anticipates the main topic of Part Three. The Chinese regime is more rational than the US government because, for one thing, the Chinese are for the most part free of libertarian lunatics and fundamentalist fanatics. And

they're governed by a group of technocrats who would never dream of doubting the reality of global warming.

NOTES

[1] See Daniel Schulman, *Sons of Wichita: How the Koch Brothers Became America's Most Powerful and Private Dynasty* (New York & Boston: Grand Central Publishing, 2014), ch. 12; Charles D. Koch, Full Transcript of Charles Koch's Interview with *Fortune*', 12 July 2016, http://fortune.com/2016/07/12/transcript-charles-koch-fortune/ (13 May 2018). Also Jim Tankersley, 'Inside Charles Koch's $200 million quest for "A Republic of Science"', *The Washington Post*, 3 June 2016.

[2] Michael Polanyi, 'The Republic of Science: Its Political and Economic Theory', *Minerva* 1 (1962): 54-73, reprinted in vol. 38 (2000): 1-32. For an intelligent and entertaining account of the sloppy use, or misuse, of science in the public sphere, see Ben Goldacre, *Bad Science* (London: Fourth Estate, 2008).

[3] Polanyi, 'The Republic of Science', 1. The quotes in the next few paragraphs are from pp. 1–17.

[4] Charles D. Koch, as quoted by Jim Tankersley, 'Inside'.

[5] Koch, interview with *Fortune*',

[6] Polanyi, 'The Republic of Science'.

[7] See Jonathan Watts, '"No doubt left" about scientific consensus on global warming, say experts', *The Guardian*, 24 July 2019, citing three recent studies published in the top journals *Nature* and *Nature Geoscience*.

[8] See the excellent history by Deborah R. Coen, *Climate in Motion: Science, Empire, and the Problem of Scale* (Chicago & London: University of Chicago Press, 2018).

[9] The institute is now the Zentralanstalt für Meteorologie und Geodynamik (ZAMG) and is located on the other (north) side of the city from the site of the original institute.

[10] Karl Kreil, *Die Klimatologie von Böhmen* (Vienna: Gerold's Sohn, 1865), 3, 2, cited in Coen, *Climate in Motion*, 19 (translation modified).

[11] See Christa Hammerl, 'Viennese School of Climatology', in *Climate Science*, Oxford Research Encyclopedias, https://oxfordre.com/climatescience/view/10.1093/acrefore/9780190228620.001.0001/acrefore-9780190228620-e-701 (10 May 2019)

[12] Coen, *Climate in Motion*, 18-19.

[13] Carlo Rovelli, 'Science Is Not About Certainty', *New Republic*, 11 July 2014; available at https://newrepublic.com/article/118655/theoretical-phyisicist-explains-why-science-not-about-certainty (20 Jan 2016).

[14] See Karl Popper, *The Logic of Scientific Discovery* (London: Routledge, 1959).

[15] United Nations Framework Convention on Climate Change, 1992, article 3, section 15. Section 3 reads: 'The Parties should take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects. *Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures* … taking into account that policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost.' (Emphasis added)

[16] 'Each finding is grounded in an evaluation of underlying evidence and agreement. A level of confidence is expressed using five qualifiers: very low, low, medium, high and very high, and typeset in italics, for example, *medium confidence*. The following terms have been used to indicate the assessed likelihood of an outcome or a result: virtually certain 99–100% probability, very likely 90–100%, likely 66–100%, about as likely as not 33–66%, unlikely 0–33%, very unlikely 0–10%, exceptionally unlikely 0–1%.' IPCC 2018 SR15, 6, fn3*.

[17] UNSCEAR report *** ref. from Tony.

[18] Joseph Fourier, 'Mémoire sur les températures du globe terrestre et des espaces planétaires', *Mémoires de l'Académie Royale des Sciences* (1827) 7: 573, 587. For a good account of Fourier's contributions in this context, see James Rodger Fleming, *Historical Perspectives on Climate Change* (New York: Oxford University Press, 1998), chapter 5.

[19] John Tyndall, 'On Radiation through the Earth's Atmosphere', 23 January 1863, Proceedings of the Royal Institute of Great Britain, 4 (1851-66): 4 - 5; cited in Fleming, *Historical Perspectives*, 71.

[20] http://doc-snow.hubpages.com/hub/Global-Warming-Science-In-The-Age-Of-Queen-Victoria. (4 July 2013).

[21] John Tyndall, 'On the Absorption and Radiation of Heat by Gases and Vapours, and on the Physical Connection of Radiation, Absorption, and Conduction', *Philosophical Magazine*, series 4, 22 (1861):276-77; cited in Fleming, *Historical Perspectives*, 73.

[22] ** Source of Mauna Loa chart. For the latest temperatures and CO_2 concentrations, see the Global Climate Dashboard on the Climate.gov website of NOAA, https://www.climate.gov (26 Feb 2019).

[23] S. J. Vermeulen *et al*., 'Climate change and food systems', *Annual Review of Environmental Resources* 37 (2102):195–222.

[24] David Archer, *The Long Thaw: How Humans Are Changing the Next 100,000 Years of Earth's Climate* (Princeton and Oxford: Princeton University Press, 2009), 11 (emphasis added).

[25] Matthew Collins et al., 'Long-term Climate Change: Projections, Commitments and Irreversibility', in T. F. Stocker et al., eds, *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge, UK and New York: Cambridge University Press, 2013), 1106.

[26] Tony Barboza, Los Angeles Times, '2018 was one of the hottest years on record and this year could be even hotter'. Phys.Org, 8 February 2019 https://phys.org/news/2019-02-hottest-years-year-hotter.html (26 Feb 2019).

[27] Damian Carrington, '2016 hottest year ever recorded—and scientists say human activity to blame', *The Guardian*, 18 January 2017. NASA, 'Carbon dioxide hits new high', Global Climate Change: Vital Signs of the Planet, https://climate.nasa.gov/climate_resources/7/(20 Jan 2017). Meilan Solly, 'Carbon Dioxide Levels Reach Highest Point in Human History', Smithsonian SmartNews, 15 May 2019, https://www.smithsonianmag.com/smart-news/carbon-dioxide-levels-reach-highest-point-human-history-180972181/ (16 May 2019).

[28] Michael Marshall, 'The History of Ice on Earth', *New Scientist*, 24 May 2010 (see also the website snowballearth.org); Michon Scott and Rebecca Lindsay, 'What's the hottest Earth's ever been?', The National Oceanic and Atmospheric Administration's Climate.gov website (2014), https://www.climate.gov/news-features/climate-qa/whats-hottest-earths-ever-been (20 March 2014).

[29] See John Cook et al., 'Quantifying the consensus on anthropogenic global warming in the scientific literature', Environmental Research Letters, vol. 8, no. 2 (2013), http://iopscience.iop.org/article/10.1088/1748-9326/8/2/024024;jsessionid=E585119237A0BB6629321071A85499F5.c1.iopscience.cld.iop.org#top. W. R. L. Anderegg, 'Expert Credibility in Climate Change', Proceedings of the National Academy of Sciences, vol. 197, no. 27 (2010): 12107-09.

[30] See, for example, the joint statement by the G8+5 Academies, 'Climate change and the transformation of energy technologies for a low carbon future', May 2009 (signed by the National Academies of Sciences of Brazil, Canada, China, France, Germany, India, Italy, Japan, Mexico, Russia, South Africa, the U.K. and the USA. Also the letter to the US Senate sent the same year by the presidents of 18 scientific societies: http://www.aaas.org/sites/default/files/migrate/uploads/1021climate_letter1.pdf (1 Sep 2012). Academies, May 2009; available from www.nationalacademies.org/includes/G8+5energy-climate09.pdf (11 May 2013). For more details and references, see this page on the website of the National Aeronautics and Space Administration: http://climate.nasa.gov/scientific-consensus/, which includes a link to a list of

'the nearly 200 worldwide scientific organizations that hold the position that climate change has been caused by human action'.

[31] All four reports from 2014 are available on the front page of the IPCC website at www.ipcc.ch. An excellent and readable account of the findings of the fourth IPCC report, from 2007, is David Archer's book with Stefan Rahmstorf of the Potsdam Institute for Climate Impact Research, The Climate Crisis: An Introductory Guide to Climate Change (Cambridge and New York: Cambridge University Press, 2010). Also recommended is 'The Visual Guide to the Findings of the IPCC' by Michael E. Mann and Lee R. Kump, Dire Predictions: Understanding Climate Change (New York: DK Publishing, 2015), which also covers the findings of the fifth IPCC report.

[32] 'The SYR was made possible thanks to the voluntary work, dedication and commitment of thousands of experts and scientists from around the globe, representing a range of views and disciplines.' IPCC, 2014: *Climate Change 2014: Synthesis Report.* Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp., v.

[33] *IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation*, prepared by Working Group III of the Intergovernmental Panel on Climate Change: O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. von Stechow (eds), (Cambridge UK and New York: Cambridge University Press, 2011), ix (available at http://srren.ipcc-wg3.de/report). A full account of how the IPCC's assessment reports are prepared can be found at http://ipcc.ch/activities/activities.shtml.

[34] See, for example, Linda Qiu, 'The Baseless Claim that Climate Scientists are "Driven" by Money', *New York Times*, 27 November 2018.

[35] Jeffrey Kluger, 'Senator Throws Snowball! Climate Change Disproven!' (includes video), TIME magazine, 27 February 2015 http://time.com/3725994/inhofe-snowball-climate/ (5 Mar 2015).

[36] See, for example, Judah Cohen et al., 'Warm Arctic episodes linked with increased frequency of extreme winter weather in the United States', *Nature Communications*, vol. 9, article 869 (2018).

[37] Donald J. Trump, tweet, 21 November 2018, https://twitter.com/realDonaldTrump (24 Nov 2018).

[38] http://www.parliamentspeakers.com/Speaker/Christopher+Monckton++Viscount+Monckton+of+Brenchley

[39] Leo Hickman, '"Chemical nonsense": Leading scientists refute Lord Monckton's attack on climate science', *The Guardian*, 21 September 2010. A link on the *Guardian* website pointed me to another good piece on Monckton,

which I had missed seeing, by George Monbiot: 'Monckton's climate denial is a gift to those who take the science seriously', *The Guardian*, 8 June 2010.

[40] 'Climate Scientists Respond to Christopher Monckton Testimony' (September 2010), http://www.skepticalscience.com/Monckton-response.pdf (accessed 2 October 2010). Monckton, cited in Hickman, 'Chemical nonsense'.

[41] Tom Arup, 'Academic fury over Monckton talk at Uni', *The Sydney Morning Herald*, 30 June 2011; Graham Readfern, 'What the World's Richest Woman, Gina Rinehart, Thinks about Climate Change', DESMOG, 27 June 2012, https://www.desmogblog.com/what-world-s-richest-woman-gina-rinehart-thinks-about-climate-change (21 July 2017).

[42] Graham Readfearn, 'Gina Rinehart company revealed as $4.5 million donor to climate sceptic think tank', *The Guardian*, 20 July 2018.

[43] In August of 2018, after unprecedented heat waves all over the world, the Australian government gave up on an energy policy that would have restrained emissions, and followed the US down the path of maximising burning of fossil fuels. See Damien Cave, 'Australia Wilts from Climate Change. Why Can't Its Politicians Act?', *New York Times*, 21 August 2018.

[44] Charles Koch, cited in Tankersley and Mooney, 'What Charles Koch really thinks about climate change', *The Washington* Post, 6 June 2016.

[45] Oliver Milman, 'James Hansen, father of climate change awareness, calls Paris talks "a fraud"', *The Guardian*, 12 December 2015.