

The importance of science and humanities for democracy – a sketch

Harry Collins

From the high point for science to the 1960s

The high point of science in ‘The West’ was in the aftermath of the Second World War. Radar and penicillin had undoubtedly helped to win the war in Europe and the atom bomb, the release of that almost miraculous form of energy, had persuaded Japan not to fight to the death of most of the soldiers on both sides and most of its citizens. In the decades after the war, ‘power too cheap to meter’ was promised from the domestication of the atom bomb, and a British reactor called ZETA was going to tame the power of the hydrogen bomb too. Meantime, the world was becoming smaller with the jet engine, while poverty was being understood and conquered with Keynesian economics. To someone like me, born in the UK in 1943, the 1950s may have been a dull and dreary decade with food rationing and dress codes as strict as uniforms, but there was never any doubt that things would get better with science exploited under the post-war settlement and the need for growing equality within nations unquestioned. Of course, in some places this growing equality was being brought about through violence and oppression but even left-leaning totalitarianism seemed like a bad episode rather than the future – the idea behind it was a good one.

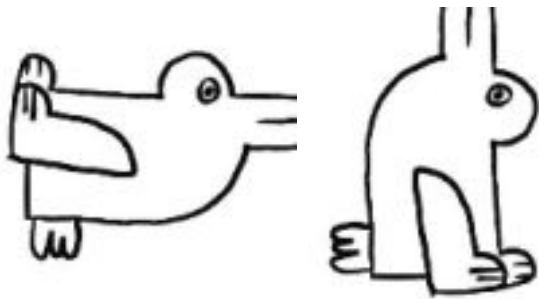
I grew up loving science and its products but things were to change for science in the 1960s. ZETA didn’t work and we are still waiting for the promise of fusion power to be fulfilled – it seems to shrink away every time we get near. The wonderfully sleek Comet passenger jet turned out to be the site of the discovery of metal fatigue in pressurised airplane bodies and it cost a lot of lives. And even the atomic

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fission power too cheap to meter turned out to leave an expensive and poisonous legacy and potential dangers for the present and future.

At the same time, our understanding of how science worked was changing in the sixties along with the demise of the sensible hemline and the trilby hat. The trigger for this was probably a little book called *The Structure of Scientific Revolutions* published by Chicago University Press in 1962, and said to be the best-selling academic book of the Twentieth Century. As often happens, this book had been anticipated by others but they weren't noticed until long after they were published whereas Thomas Kuhn's book made an impact, perhaps because the 1960s was the right decade for radical ideas like this. The key idea was that science did not progress smoothly like a jigsaw puzzle deterministically



building toward an ever more complete picture but that there were sudden ruptures when scientific ideas changed wholesale. The analogy was that of the 'gestalt switch' – one moment you see the line drawing as a duck and the next as a rabbit and you can't see them

both at once.

The classic gestalt switch, or paradigm revolution, was from Newtonian physics to Einsteinian physics. It wasn't just a change in perception but a change in our idea of what the world was made of. Under Newton, mass and energy were each preserved; with Einstein they were interchangeable. So even the meaning of experiments could change when the 'paradigm' changed and that's why Michelson and Morley could have such a different interpretation of their famous experiment – a failed Earth speedometer – than Einstein and Hawking – a proof of the fixedness of the speed of light. Now you could have groups of scientists occupying different worlds like separate tribes in the Amazon rain

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forest, speaking different languages with their worlds filled with different features. Suddenly, science had a social structure: it was no longer just one big jigsaw puzzle where the shapes of the pieces led inevitably to a unique picture.

What is it like to have a social structure? The Fractal Model of Society

The key sociological idea that fits this new image comes from the sociology of knowledge. It's an easy idea to grasp but utterly terrifying if you think about it. It tells you that what you believe to be the case is not a result of your brilliant deductions or observations but a social accident. To 'get it' you just have to think about why you believe most of the things you believe and why you act in most of the ways you act. Thinking and acting are two sides of the same coin according the great philosopher Wittgenstein. For instance, why do you speak the native language you speak (e.g. English), which in turn causes you to act in various taken-for-granted ways (for example if you didn't have the word/concept of 'germ' you wouldn't use disinfectant). This is not a choice – you don't reconsider the existence of germs every time you use bleach on a kitchen surface or cut into someone's skin, it just comes with the language. And this language you use is a matter of where you were born! Why do you cleave to your religious beliefs (or why did you in your early life)? Again, because of where you were born. Do you play polo? Pretty unlikely unless you were born to a very narrow group of people. And so on. I like to use what I call the Fractal Model of Society (FMS) to think about this; it's represented in Figure 1.

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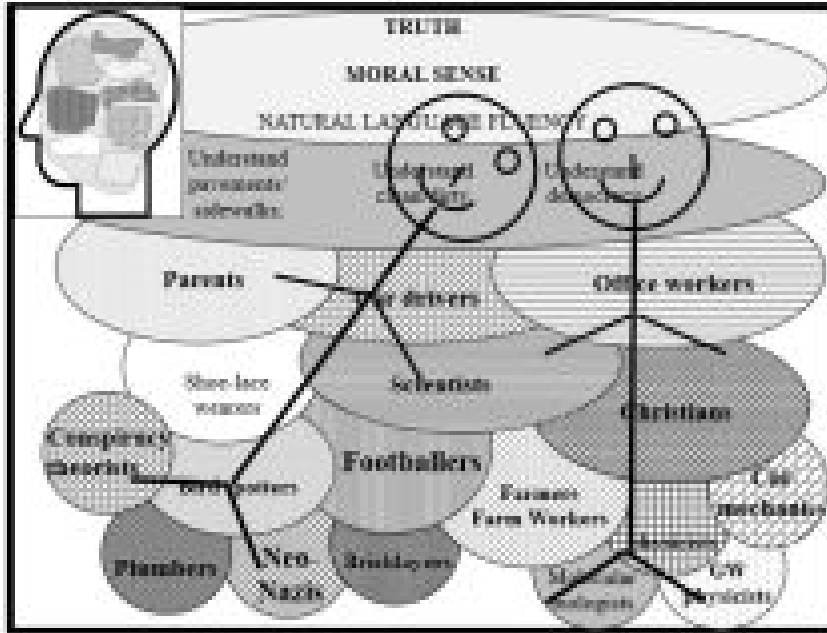


Figure 1: The fractal model of society and individuals

A fractal is a mathematical construction in which the pattern of the whole is reproduced in the pattern of its elements. A physical exemplar is the cauliflower. Each floret in a cauliflower is like a smaller reproduction of the cauliflower as a whole, and each sub-floret of the level above is the same and so on all the way down to the level of a few unstructured cells. The florets and sub-florets are models of the whole while the whole is the sum of all the levels of smaller models of itself. Societies are the same – they are made of a cascade of smaller and smaller sub-societies.

There are some disanalogies with the mathematical fractal but the important thing is that all the elements of this instantiation of a fractal is not the similarity of shape and material of each repetition but the fact that they are all societies or sub-societies and are the same in the respect that coming to be a member of them is always a matter of ‘socialisation’ (except shoelace wearers are an exception, not being a social group). Socialisation means spending time with other members of the group at whichever level we are talking about. This is vital if you are to acquire the group’s taken-for-granted-ways of being or what is usefully called their ‘tacit knowledge’, as opposed to their ‘explicit knowledge’. Very

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roughly, explicit knowledge can be written down and carried about and transferred via the post and the internet and so on; tacit knowledge can only be acquired by immersion in the life of the social group in question. I wrote a whole book called *Tacit and Explicit Knowledge* but it's quite hard going in places.

So, let's start with a few examples. When you were a baby and learning to speak your native language, you learned a huge body of grammatical rules without having any idea that you were learning them. For instance, if you were learning English, you were learning that the verb goes in the middle of the sentence (whereas for German speakers it tends to go at the end). But at the time you were learning this, you did not know what a verb was or what a sentence was so you could not possibly have been learning it explicitly. When you learn a foreign language you will never become fluent by learning vocabulary and grammatical rules from books, you have to spend time with speakers of the language, engaged in conversations if you want to become fluent because all that unspoken stuff has to seep in.

The first academic paper I ever wrote (published in 1974) applied this idea to fluency (i.e. success) in learning to build a new kind of laser – a Transversely Excited Atmospheric Pressure, Carbon Dioxide Laser. I looked to see how people (other than the inventor) learned to build them. And it turned out that no-one who tried to build one from published papers and circuit diagrams succeeded in making their TEA-laser work even though it looked like a TEA-laser and used many of the same parts. I was lucky because all those who spent some time in the laboratory of someone else who had a working TEA-laser, did succeed in making a working TEA-laser when they went home, so I had a very clean result. I managed to work out some features of why this might have been. The paper I wrote is still being cited 50 years later to explain things like why it is hard for US industry to transfer the expertise from Taiwan to make the latest computer chips.

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A final example makes the point that some tacit knowledge can be made explicit with enough effort but some can't. A classic instance is riding a bike. Riding a bike is like learning a language – we can learn to balance without knowing how we do it – without knowing the rules. But we know those rules can be made explicit because we can build robots that can ride bikes. But riding a bike in traffic is another matter: for instance, it depends on catching the eye of motorists at junctions to work out if they are going to let you go, and so on. That's like the more subtle uses of language, like when to use swear words as a joke – very difficult to get it right without really understanding the society. And in both cases, the rules vary from one society to another. Have you seen people riding bikes in China?

Going back to Figure 1, *you* are like one of those stick figures. Who 'you' are depends on your experience of immersion of a range of social groups, large and small. You feel like the inserted head in the top-left corner with all those bits of 'knowledge' that you've chosen to harvest over years of upbringing and education but really you're a 'molecule' put together out of 'atoms' which, in this strange world, are each much larger than you – the atoms are social groups in which you've been immersed. Look at where the stick figure's head, body and limbs touch the fractal model and you'll understand what one of those stick figures thinks of as 'itself'. The self is a collection of experiences and the two stick figures are very different. Notice, that they share the top two groups. The very top oval is common to every human society but the next one down is how that top oval is cashed out in any particular nation or tribe. Then, if we are dealing with Western societies, come the many cascading 'sub-florets' which offer alternative selves. The key idea is that in respect of any sub-group you should think of yourself as something like a thermometer dipped in heated liquid. The thermometer registers a temperature but the temperature does not belong to the thermometer, it belongs to the liquid. What you as a person do throughout your life is absorb different 'temperatures' from different bodies of liquid and store them all up, though you have to use the analogy in a charitable way to make it work. Just

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register what this means by thinking about what a completely different person you would be if you had been born and brought up somewhere else, like the Amazon rain forest.

The reasons that the fractal model is important are, first, because it leads us to think about what socialisation into a group consists of and, second, because it encourages us to think about the differences between the different groups. The analogy with the fractal breaks down a bit here as in a mathematical fractal all the florets and sub-florets are the same apart from their size but in the FMS the florets and sub-florets are different in terms of their contents and properties as well as their sizes. This is important when it comes to assessing the special role of science in democracy.

Ubiquitous Expertise, Specialist Expertise and Socialisation

In the book, *Rethinking Expertise*, we put together what we call a ‘Periodic Table of Expertises’. The top line of this table consists of ‘ubiquitous expertises’. Ubiquitous expertises are the expertises of every citizen in a society – the top two ovals in Figure 1 with the second oval being your particular society. Traditionally, among academics, what every citizen knows is not thought of as an expertise because an expertise is treated as something that requires special application to acquire, such as c.10,000 hours of practice. But every citizen spends a good 10,000 hours acquiring fluency in their native language so that is an expertise even though every citizen has it: you soon discover this when you go to a country where you don’t speak the language and computer scientists discovered it when they found that it was much harder to build computers with natural language fluency than to build computers that could out-perform humans at arithmetical tasks. To repeat: ubiquitous expertises are represented in the top two ovals of Figure 1, whereas those specialist abilities normally thought of by psychologists and the like as expertises aren’t encountered until we start going down the cascade of

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elements. Here, we are going to be specially interested in that part of the cascade that starts with the ‘scientist’ oval.

Let’s extract a line from the ‘Periodic Table of Expertises’ (from Collins and Evans, 2007) which can be used to represent science (Table 1).

| SPECIALIST | UBIQUITOUS TACIT KNOWLEDGE | | | SPECIALIST TACIT KNOWLEDGE | |
|------------|-------------------------------|--------------------------|--------------------------------|-------------------------------|---------------------------|
| EXPERTISES | Beer-mat Knowledge | Popular Understanding | Primary Source Knowledge | Interactional Expertise | Contributory Expertise |

Table 1: The Specialist Expertises line from the Periodic Table of Expertises

There are five kinds of scientific knowledge represented here. The crucial division is between the three left-hand kinds and the two right-hand kinds. The three left-hand ones can be acquired by those who possess only ubiquitous expertise; the two right-hand ones can only be acquired by through socialisation in the specialist domains of science.

Starting from the left, ‘beer-mat knowledge’ is named for the explanation of how a hologram works found on a beer-mat (coaster) made for the Babycham company in 1985:

A hologram is like a 3-dimensional photograph – one you can look right into. In an ordinary snapshot, the picture you see is of an object viewed from one position by a camera in normal light. The difference with a hologram is that the object has been photographed in laser light, split to go all around the object. The result – a truly 3-dimensional picture!

This is capable, presumably, of making at least some people feel that they now know something about holograms, but there is nothing you can do with it beyond pretending to know something that you don’t really.

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The second category from the left, ‘popular understanding’ is the slightly more complete understanding of things you can get from popular science books and articles, whereas the next entry, ‘primary source knowledge’, is what the ordinary citizen of an activist persuasion can gain from intense study of the formal scientific literature. In many ways it is the most dangerous category of all because the formal scientific literature is written to seem unquestionable whereas scientific knowledge at the disputed frontiers of science is just that: disputable.

To get a proper grasp of the nuances of frontier science needs immersion in the social life of the scientists in question. There are two kinds of expertise that can be acquired – the one at the far right of Table 1 is ‘contributory expertise’, which is what it takes to make a contribution to the frontier; contributory expertise is what most people think of as a ‘specialist expertise’. The second category from the right is ‘interactional expertise’, which is fluency in the spoken discourse of the specialist domain. It is possessed by all, or nearly all, of the contributory experts (there will be one or two who are just not very good at explaining themselves even when they understand). It is tempting to refer to interactional expertise as the ability to ‘talk the talk but not walk the walk’, but this is to misunderstand the vital importance of language and spoken discourse within specialist (and, indeed, all other) groups. Specialist groups have still more specialist groups within them, a little further down the fractal. In Figure 1 we can see scientists, with physicists below them, and gravitational wave physicists (GW physicists) below them, and, though they have not been drawn, there are gravitational waveform calculators, and interferometer mirror specialists and vacuum system designers, and so on, below them. These groups of specialists would not be able to work with a productive division of labour if they could not speak the common language of gravitational wave physics, a language which contains within it the tacit knowledge of the practice of gravitational wave physics – see Figure 2.

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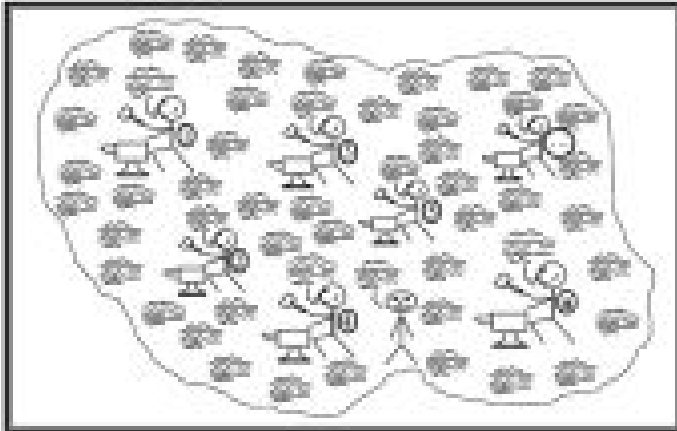


Figure 2: *The specialist group has specialist skills, 1-n, held together by a common language -- the wavy lines. To have interactional expertise is to be fluent in the language.*

There are a few people who have interactional expertise but no contributory expertise, such as social analysts like myself, or the technical managers of large scientific projects, but mostly interactional expertise is the engine oil of specialist science – it keeps the engine turning and it is the discourse that transmits the tacit knowledge and enables it to be shared.

Meta-expertise

In respect of the InSECT project, another line of the Periodic Table deals with meta-expertise (Table 2).

| META- EXPERTISES | EXTERNAL (Transmuted expertises) | | INTERNAL (Non-transmuted expertises) | | |
|---------------------|-------------------------------------|-------------------------|---|----------------------------|-----------------------|
| | Ubiquitous Discrimination | Local Discrimination | Technical Connoisseurship | Downward Discrimination | Referred Expertise |

Table 2: *The Meta-Expertises line from the Periodic Table of Expertises*

For our purposes we do not need to go through this line in detail, we need only to grasp the general idea of meta-expertise – it is expertise about expertise. The source of the general idea is the top levels of Figure 1 because the kind of meta-expertise we want to talk about here is ubiquitous expertise: it is what tells citizens whom to consult when they have a problem. It is our meta-expertise, acquired through a high level of socialisation, that tells us to go to a garage mechanic when our car breaks down,

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to go to a medical doctor (that is, in our society rather than a witch doctor in some societies) when our health breaks down, and listen to doctors and scientists (rather than politicians), when we want to know whether vaccination is safe. The entire point of the InSECT project is to get the ordinary citizen to know why to choose scientists as opposed to other available sources when they have to make a decision that involves understanding the observable world, but not to do this by pretending science is perfect.

Once upon a time – after WW2 when the business of science seemed simpler – making this decision was also simple: science was unquestionably the superior form of knowledge about the observable world and scientists were unquestionably the people to turn to. But since the 1960s, matters have become more complicated. This was partly because bits and pieces of science went visibly wrong. It was also partly because historians, philosophers and sociologists, and even literary theorists, showed how scientific knowledge was less obviously the occupant of some high ivory tower well above and isolated from mundane society, and because, in more recent times, technological advances such as social media and ChatGPT and its counterparts, have eroded the fractal nature of society, and because populist leaders have eroded truth itself. What we have to do is rescue science from these assaults on its credibility and, without going backwards and pretending that all is still just as it was in the ‘once upon a time’, convince people that science is still the way to bet at the meta-expertise bookie when choices involve the observable world.

Why Science Isn't Perfect

To make sure we are not simply going back to mythological times, let's list some of the problems we now understand.

First, the speed of politics is faster than the speed of science. Events in the real world of politics often need answers far sooner than science is ready to give them. Anything involving humans is almost

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certain to encounter this problem – anything involving health, wealth, or education, will involve it:

Covid lockdowns didn't anticipate the educational downsides or the level of non-compliance;

Keynesian economics didn't anticipate stagflation, and neoliberal economics cannot cope with the deleterious economic, health and social effects on non-beneficiaries; the agricultural green revolution didn't envisage problems of widespread obesity; and those who used new food technologies to extend the lifespan of foods didn't appreciate the downsides of an ultra-processed diet.

Second, science's experimental technology, such as replication, does not work as advertised.

Experiments are often far more difficult than they are said to be when well-established sciences are used as the educational model for research science. Even famous scientists get this wrong over and over again. The InSECT course will describe how Albert Einstein and Steven Hawking, along with most physics textbooks on the library shelf, misdescribe the famous Michelson-Morley experiment, treating it as though it was an established piece of science rather than a pioneering piece of science. In pioneering science no one can be sure whether their experiments are working or not because the meaning of 'working' has not yet been established. This means that science at the frontier depends on trust of other's experimental abilities and that trust has to be developed in small groups with strong boundaries because at the frontier so much is open to question that science would be impossible unless the scope for questioning was restricted. Scientists have to build the body of 'tacit knowledge' that supports experimental work through social interaction and linguistic discourse, building the language that defines their world – a mini-paradigm based on a series of mutually accepted assumptions, mostly tacit. In this respect science has a lot in common with literature – they are both about the frontiers of language and the interpretation of written products, and one of the jobs we have is to show why it is that in spite of this, science and literature are different.

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Not being a literary scholar I am not quite sure how this looks from the other side, but I know I would have loved to have been taught in a class where the humanities approach and the scientific approach to interpretative flexibility would have been contrasted. I can only guess that it would start with the fact that humanities teaching would turn on and celebrate the flexibility of interpretation of literary works, perhaps culminating in Roland Barthes' 'the author is dead' – all being in the hands of the interpreters. The science, teacher, on the other hand, would be at a loss to know what to do when interpretative flexibility is revealed. What do you do when Albert Einstein and Stephen Hawking as well as all those textbooks misdescribe the Michelson Morley experiment? One thing you can do is look very closely at what they said and find an interpretation which is less grossly misleading, such that they were only saying that Michelson and Morley and all the subsequent experiments including that of Dayton Miller, for which he was awarded a physics prize for finding a variation in the speed of light, were really proving that no variation consistent with the speed of the Earth through the aether could be found. If you look hard you can give the benefit of the doubt to Einstein but it is very hard in the case of Hawking. So there is some energy to be extracted through debate about science writing compared to humanities writing.

But maybe the thing reflects back on humanities writing too. After all, if it true that it is hard to find an excuse for Hawking writing what he did, doesn't this mean that author is not as dead as Roland Barthes said he is? The useful term is 'affordance': in logic any text can be interpreted as anything the reader likes, but some texts 'afford' certain interpretations more readily than others and the humanities texts we are focussing on afford a lot because that is what makes them stand out as excellent works. But now think about the affordance of, say, Picasso's painting 'Guernica' – a painting that is far from realism yet seems to have only one meaning – and that is before we get to the realism of, say a Constable, which surely cannot be *easily* read as a commentary on the violence of war. And think of a book like

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1984 – that too was surely written to minimise its affordances. Constable, Picasso, and Orwell are, strangely, trying to produce in the manner of scientists in respect of the interpretability of their works. Those authors are doing everything they can to be treated as not dead by their ‘readers – like scientists! The languages are different to scientific languages but their means of transmitting what they mean are enormously powerful and very constrained in terms of interpretation.

A Philosophical Exercise to Bring Out the Difference Between Established and Frontier Science

Actually, you can see the difference between established science and frontier science in a school laboratory with the simplest of pieces of practical work. But to see the difference needs a kind of philosophical skill: it is the skill needed to ‘re-imagine’ an established school laboratory practical as though it was a frontier experiment; when you do that you can, for the moment, imagine yourself into the position of a frontier scientist building a new paradigm. The practical we suggest is measuring the boiling point of water but you can try the same re-imagining trick on other simple measurements if you wish. With the boiling point of water, you boil a flask of water and dip a thermometer into it – and hey presto, the temperature comes out as 100° Celsius. Except, that if you examine the thermometer very closely it probably does not read quite 100° – it almost certainly reads a little more or a little less. Now, the philosophical trick is to imagine you are the first person in the world doing this and instead of just saying ‘oh yes, 100°’ – you say ‘Ah! The boiling point is not quite 100° but a little more (or a little less)’. Then you might find yourself involved in a scientific controversy.

If you are a ‘little more-ist’ you might find yourself disagreeing with the ‘little less-ists’ and you have the problem of how you are going to settle it. Because you are making this measurement for the first time, you can’t take a look at the result to settle it, because the correct result is exactly what the dispute is about. So you might start to argue about whether the ‘little less-ists’ have a proper thermometer or

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have been given faulty ones, or the ‘little less-ists’ might find themselves arguing that the ‘little more-ists’ contaminated the water they were using by dropping some dust into the beaker, and then you’ll all have to start thinking about whether you carried out each step carefully enough in the first place and how much cleaning of the apparatus you should have done at the outset and you could all find yourself arguing about who was capable of cleaning things properly and who only thought they were, but weren’t careful enough with their clothing and hair – and so on and so on. This way you will be exploring how real frontier experiments go. You might want to look up the history of cold fusion or some such to see that frontier experiments do have a tendency to go this way when their results seem too unexpected – scientists start questioning others’ qualifications or scientific skills, and so on.

Fringe Science, Controversies, and the Like

Now, you can see why meta-expertise is so hard. If you take the boiling water example and you find that most people are ‘little more-ists’ you can imagine a few ‘little less-ists’ going off and forming an alternative science – after all, they think their results are perfectly reasonable: there is nothing you ‘little more-ists’ can do to convince them they are wrong – they are sure they it is you who are wrong. And off they can go and if they are sufficiently persuasive to others, they can form a ‘fringe science’ of like-minded believers. If you are an outsider and you have to decide on something that turns on the exact boiling point of water, how are you going to make the meta-judgement between the mainstream and the fringe? It isn’t going to be a matter of doing some scientific thinking – there is no scientific thinking that bears on it. (Of course, there is once you abandon the philosophical experiment and think of measuring the boiling point of water as accepted science, but part of the skill of what we are doing here is to avoid that easy option.)

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Now you should be able to start to get a ‘feel’ for how real scientific controversies work. You should not be surprised that there are fringe sciences that grow out of clever scientists choosing not to accept some taken-for-granted assumption upon which a scientific ‘paradigm’ rests and choosing to adhere to an alternative paradigm. You should not be surprised that such people are well-qualified scientists working in universities. You should not be surprised to know that there are groups of such people who publish their own journals that look like ordinary scientific journals. There’s a whole clan of such people who still refuse to believe in the theory of relativity, some of whom have jobs in physics departments of universities. You should not be surprised that there are well qualified scientists who are ready to put their names to papers that say that anthropogenic climate change is a myth – papers on which Donald Trump and his acquaintances in the fossil fuel industries can draw. And you should not be surprised to find that the tobacco industry could find qualified scientists to question the relationship between lung cancer and cigarette-smoking, nor that Thabo Mbeki, the one-time President of South Africa, could find support from famous scientists for his view that anti-retroviral drugs would not work and should not be given to pregnant women. And, of course, you should not be surprised to discover that such fringe views are promulgated on social media. After all, it is the establishment that holds the mainstream views just as in our philosophical experiment with boiling water it will be the establishment that promulgates the lie that it is exactly 100° while no one you know has ever seen such a result.

Making the Meta-Expertise Judgement to trust the mainstream consensus

Given all that, how can you make the meta-expertise judgement about who to trust? Let us provide the answer up-front before trying to explain why: the answer is that you should trust the consensus found in mainstream science. Very occasionally it may be wrong, but it is the way to bet so long as the fractal model of society still has integrity and so long as science remains largely uncorrupted.

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Go back to Figure 1 – The Fractal Model of Society – and you can see the question of meta-expertise as a choice between groups well down the fractal. Suppose I want to know whether gravitational waves have been seen: I have a choice between, say, the group of gravitational wave experts and a fringe group who believes the whole thing is a fraud. The fringe group might be convinced it must be a fraud because of the ‘rubber-ruler problem’. The rubber-ruler problem is that gravitational waves cannot be seen because they are ripples in spacetime and they will distort any measuring instrument in just such a way that a wave will have no visible impact. I spent 45 years with the gravitational wave physicists and can assure you that they were aware of this objection and that one of their number wrote a paper refuting it. I can tell you that the community, more than 1,000 strong, accepted the argument in this paper. I will also tell you that I never quite understood this paper – I’m not quite good enough at the mathematical end of physics. But I knew the man who wrote it very well and trusted him completely when he told me that he had solved the problem, and I knew many of the people who did understand the paper it and did accept the argument and I trusted them too. So, when I found that the discovery of gravitational waves – announced in 2016 – was being challenged via the rubber-ruler problem I was not impressed. But when in March 2025 I was sent a thick, spiral-bound book, laying out the rubber-ruler problem and still insisting that the discovery was a fraud, I became curious and got in touch with the author, who had sent it to me. The question I asked him was why he was still supporting his view given that by now a couple of hundred or so gravitational waves had been detected, all matching the predicted waveforms. He insisted that because of the rubber-ruler problem they *must* all be fraudulent. But I know many of the discoverers and, although there is a logical possibility that they were all cheating, the logical possibility of something does not make it credible. I’m sorry that the paper that refutes it is still just a bit too hard for me to understand – maybe one day I’ll spend some more time discussing it with its author – but right now I’m ready to trust the view of all these people I know; I think it is completely

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incredible that they are all involved in a conspiracy, about as incredible as that the Earth is flat. And, bear in mind, when it comes to frontier science, it won't work in the absence of trust; we're all, including the scientists, in the position of having to trust things we can't prove for ourselves.

Trust and truth

The specialist groups in the fractal model create credibility on the way to creating new truth and the way they do it is by forming trustworthy communities. Those communities are trustworthy because of the way their boundaries are guarded – with very rare exceptions (I'm one), you cannot get into them unless you have been socialised into the larger group in which they all embedded – 'scientists' – and unless you have served an apprenticeship that has given you the skills required for entry into one of the narrower groups below scientist – in this case gravitational wave physicists. That's what enables such a group to be able to do science without being continually distracted by scientists such as those who refuse to give up on the rubber-ruler problem in spite of the internal consensus among mainstream scientists that it has been solved.

Why the meta-expertise problem changes with social media and ChatGPT

With the internet, Figure 1 is no longer a faithful representation of society. This is because the sharp boundaries to the sub-societies represented in the Figure are dissolving; the whole figure threatens to turn into an amorphous mass. The erosion of the fractal model is illustrated in Figure 3.

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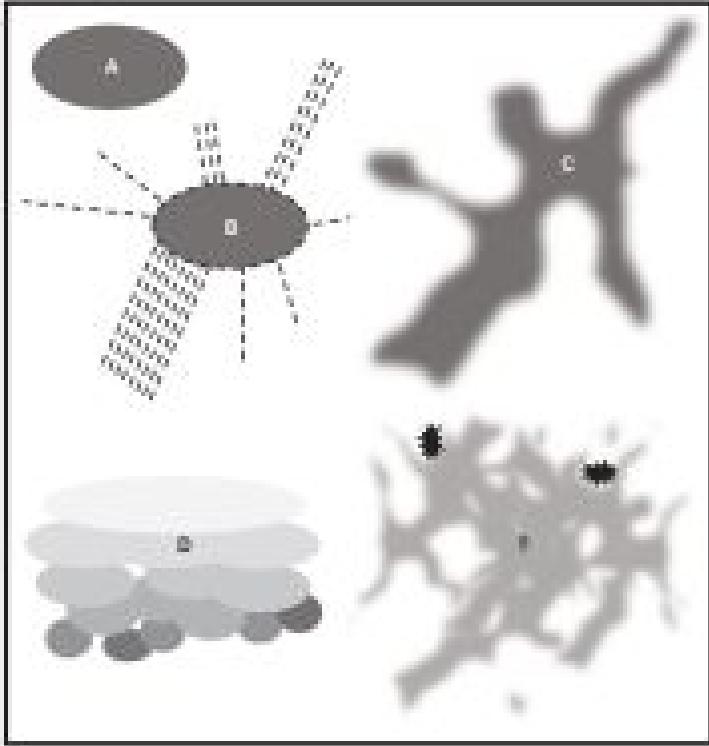


Figure 3: Erosion of the fractal model with social media and AI

If panel A in Figure 3 is one of the mid-range groups in the fractal model, its boundaries are no longer secure. Its boundaries are now crossed by multiple links, as shown in panel B. Contributions made via social media can come from anywhere. With social media it is no longer the case that all the seeming contributors are members of a small group who know and trust each other through face-to-face meetings; in the case of the gravitational wave group, we would meet face-to-face in conferences and workshops all over the world around half-a-dozen times a year. At the height of my involvement I knew most of the people in the thousand strong community and, through endless discussion, knew who to trust and who not to trust quite so much when there was an internal dispute. But with social media the contributors can disguise themselves as members of a local group; they may not fool insiders but citizens exercising their meta-expertise cannot see through the disguises if the pretenders create an ‘illusion of intimacy’ – that’s part of the skill of being a successful user of social media – to outsiders, other outsiders pretending to be insiders can be just as persuasive as the trusted sources inside the

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boundaries. And, from the inside, the way the boundaries are being transformed for consumption is the outside world, is not apparent. The dashed lines in panel B represent internet links, supported by the illusion of intimacy, coming from near and far, sometimes organised and sometimes not, and turning the well-bounded institutions and groups (such as panel A) that make up the fractal into fuzzy-edged amorphous shapes visible to citizens, that reach into mysterious social spaces (panel C). The well-defined structure of human knowledge, represented by the fractal model, goes through a social liquidiser and comes out as a smoothie. The well-ordered fractal model based on local trust (panel D), is replaced by something amorphous (panel E). This model of knowledge is far more readily subject to control by aggressive centres of economic and political power, as represented by the black stars. That is what we see happening as politics invades the once secure boundaries of the specialist sciences. If citizens cannot tell the difference between conspiracy theories promulgated by the internet and mainstream scientific consensus – if their meta-expertise fails – then science dies. Schools and universities may be the last resort for restoring the structure of society that has always been the basis of sound knowledge. That is why *you* are so important.

AI

Artificial Intelligence in the form of Large Language Models such as ChatGPT have the same liquifying effect as social media. Their apparent intelligence comes from statistical analysis of the language found on the internet. But the language found on the internet is not structured to follow the fractal model. On the internet, anyone can say anything about anything and the basic data of LLMs is the amorphous data of panel E not the structured data coming from panel D. That's why the early LLMs had to be 'aligned' to fit with human values. The early LLMs reflected the misogynistic, racist, neo-Nazi, and bomb-making sentiments of the internet as a whole. In fact, they were reflecting what is

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found out there, and very disappointing it is. The new danger is that malign forces get control of the alignment process because alignment doesn't preserve 'human values', it preserves the values of whoever is doing the aligning.

Why trust the cult of science?

Now you might say that this sounds a bit cult-like – taking on trust the output of elite groups with closed boundaries. And preserving a meta-expertise that is based on trusting a science produced by elites with closed boundaries which cannot be verified by one's own observations is to trust a cult.

Politician Robert F Kennedy Junior is clear about this. When interviewed by Tucker Carlson on 30 June 2025, he says (https://youtu.be/w_fzlwxJZAA?si=zbmTIG9KAZ9oy-X8&t=835, about 14 minutes in):

Trusting the 'experts' is not a feature of science; it's not a feature of democracy. It's a feature of religion, and it's a feature of totalitarianism. In democracies, we have the obligation, and it's one of the burdens of citizenship, to do our own research and make our own determinations about things.

But this is crazy. We know from our classroom philosophical exercise that if we want to reach the conclusion that the boiling point of water is exactly 100° we cannot determine it for ourselves, we will have to trust the authorities, starting with the teacher. Society does not work without trusting experts, which is why we call plumbers, car mechanics and builders when we have problems that can be solved only by these 'elites'. Scientists are like plumbers, car mechanics and builders – they are craftspeople in the ways of the observable world. The difference with scientists is that their first obsession is with truth while the craftspeople you hire are sometimes not so obsessed. Science is 'craftwork with integrity'.

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Science as an Institution: The Three-column Model

At this point, we move away from the analogy with the mathematical form of a fractal. The ‘fractal model’ still describes the shape of societies with its cascade of ever more specialised groups, but in a mathematical fractal and a cauliflower, all the sub-groups are the same, whereas in the social model the sub-groups have important differences. Table 3 represents the qualities of the social group found near the centre of Figure 1, the sub-group labelled ‘scientists’. This ‘three-column model’ is what we will use to represent any of the fractal model groups, or ‘institutions’, to use social science terminology, that we want to compare with science.

The left-hand column of Table 3 is the ‘Formative Aspiration’. It is what the participants are trying to achieve through membership of the group – it is their *raison d’être* and it is what makes the group what it is. In the case of science, the *raison d’être* – the thing they exist for – is to truthfully understand and describe the observable world – to discover ‘correspondence truth’. Trying to understand the truth about the observable world is what science *is*. It is a collective practice – if others don’t agree that your claims about the observable world are correct then you have not yet done any usable science. That’s what’s going on in those smaller and more specialised groups lower in the fractal model. That’s why they keep their boundaries closed and get together to form a mutually acceptable language that captures their description of the world – the wavy lines in Figure 2. That’s how science works.

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| SCIENCE | | |
|--|--|---|
| Formative Aspiration | Formative Imperative | Procedures/methods to support formative aspiration <i>some were once thought of as 'the logic of scientific discovery'</i> |
| Collectively aspire in expert groups to find universal correspondence truth in respect of the observable world with no limit on time except for logistics | Individuals pursue moral truth by reporting findings honestly, accurately and clearly | <ol style="list-style-type: none"> 1) Assiduous observation and experiment, not preconception or revelation. 2) Disinterestedness: e.g. use of blind/double blind tests 3) Corroboration/replication; falsifiability 4) Expertise and experience vital: controlled boundaries round small groups of experts 5) <i>Locus of Legitimate Interpretation</i> (LLI) close to producers: fair criticism and response restricted to expert peers. 6) Arguments are aimed at convincing experts not citizens 7) The defeated are as much winners in terms of formative aspiration as the winners |

Table 3: The three-column model of science

Fulfilling the Formative Aspiration can be a very long job and fraught with the possibility of failure. Einstein set out the idea of gravitational waves about 100 years ago and declared that they were so weak they would be of no interest to physics. Incidentally, Einstein changed his mind once or twice about whether they exist. About 50 years ago physicists were still arguing about whether, if they did exist, they were detectable in principle – the rubber-ruler problem being a serious obstacle. But in the late 1960s a physicist called Joe Weber built an apparatus to detect them and this seemed to calm the in-principle objections. By the early 1970s, Weber was claiming to have seen them but by around 1975 hardly anyone believed him. Over the years there were about half-a-dozen claims to have made a detection but all of those claims eventually lost credibility. The first credible detection was announced in 2016. Science is hard and it can be slow.

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Moral truth and ‘scientific method’

The second column is the ‘Formative Imperative’ for individuals that follows from the Formative Aspiration. If the collective enterprise is ever to succeed, the individuals must be clear and honest. They have to practise moral truth. Moral truth is easier to achieve than correspondence truth. Moral truth is an ‘internal state’ and you have more control over your internal states than you have over your interactions with the outside world. Practising moral truth means deciding to tell the truth and not lie about your observations so that others can use what you say you have done in their own work. For that to happen, you have to be clear, not confusing, in what you say.

Moral truth may be easier to achieve than correspondence truth but it is not a trivial matter. You may think you are telling the truth but you may be failing. Group pressure is one way in which what you think is true can be distorted, and there are various psychology experiments that have shown this. The third column lists some of the things scientists do to make moral truth more readily achievable and it lists some of the other features of science that follow from the first two columns. No doubt the list could be longer. In the 1960s it was thought that these procedures were the essential logic of science, but they’re not. The first entry might be – after all, you can’t discover the way the observable world works without observing and experimenting. Now one can see how useful this table is for comparing one institution with another: some religious groups prefer revelation to observation.

The second entry is often described as the gold standard of science but it certainly isn’t. Double-blind protocols are very useful for avoiding such pitfalls as expectancy effects but they don’t guarantee the truth. For instance, if, in a drug trial, the real drug has some palpable side effects which the placebo doesn’t, it is no longer double-blind. And you don’t need a double-blind experiment to test the reliability of parachutes – which is a very good thing. The third item is an in-principle feature of

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science but a lot of argument in the '60s and '70s turned on whether it was corroboration or falsification that was the key to science. It's good to have both of them but one can manage without. Incidentally a quick comparison is the advertising employed by businesses which, essentially, shows they work with an imperative that is opposite to that of science: advertising is meant to persuade people to believe something about a product that may not be true.

As for replication of experimental findings, that seems like a philosophical imperative because if results aren't reproducible then how can we believe we have a stable world? On the other hand, now we know how difficult experiments are and how their results can be differently interpreted it is not quite so clear that replication is part of the necessary *logic* of science in practice. It's worth noting that the 'Little Boy' bomb that was dropped on Hiroshima had never been tested.

The Locus of Legitimate Interpretation

Item 4 has already been discussed at length. Item 5 has not been mentioned and here we move into a nice comparison with the arts and humanities.

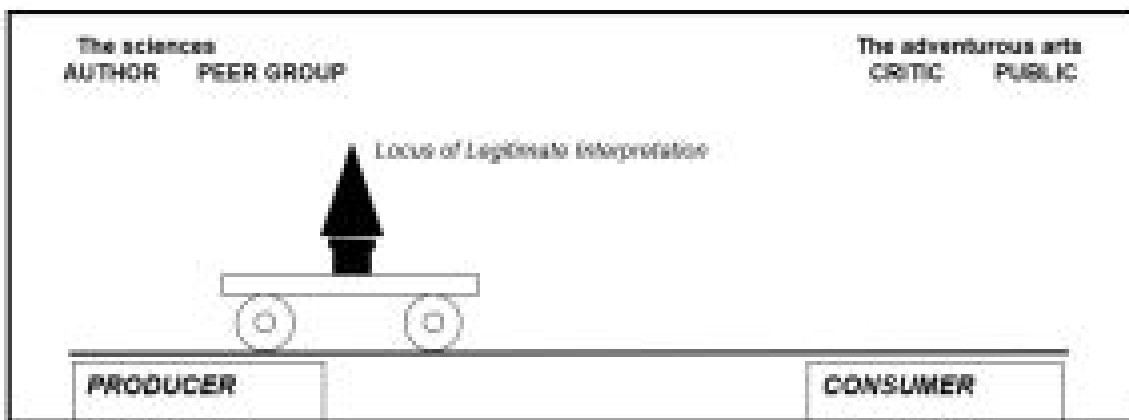


Figure 4: The Locus of Legitimate Interpretation (LLI)

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Figure 4 shows the ‘Locus of Legitimate Interpretation’ (LLI). The LLI is the ‘place’ where legitimate interpreters of scientific and other work are located. Imagine the vertical arrow travelling from place-to-place on its trolley (it makes a nice PowerPoint slide if you can do the animation). The easiest place to start is the far left with the sciences. Here the LLI is restricted to those who have been allowed entry to a specialist group because of their socialisation into science as a whole – which means they fit nicely into the three column model of science – and their apprenticeship in the specialist skills associated with the narrow topic – they be one of those contributory experts shown in Figure 2 or, just possibly, they will have only interactional expertise only. In other words, with science the LLI is close to the producers of the output. It gets a little hazy when we move to grant assessment and peer review where those making the interpretations of the value of the work may not always be members of the narrow group, but nothing is perfect.

Now slide the LLI over to the right and locate it under the adventurous arts. We now find whole new sets of legitimate interpreters drawn from a position close to the consumers not the producers – in fact the producers don’t get much say. In the case of works of art we have gallery owners, newspaper critics, and, in some cases, the general public. We don’t have those in science. It is a joke to say ‘I don’t know much about science but I know what I like’ but it may be a legitimate claim in the arts. If it becomes a legitimate claim in respect of the sciences, then something is going seriously wrong.

But is what I said above, when I said I did not quite understand the resolution of the rubber-ruler problem but I trust the people who tell me it is a solution, me saying ‘I may not know much about science but I know what I like’? No, it’s me saying ‘I may not know much about this narrow piece of science but I know who to trust, and it’s the experts.’

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Something closely linked to the idea of the LLI is the value of interpretability. We've known since the 1970s or earlier, and from our experiment with boiling water, that the findings of science can be variously interpreted. But in the arts and humanities part of the value of a piece of work may be the extent to which it affords a variety of interpretations. Think of the praise for Shakespeare in virtue of the many interpretations his plays afford and think of the critical acclaim for a novel interpretation of a well-known poem or the like. Scientific outputs may be variously interpretable but that is never counted as a good thing – the aspiration will always be to make an output clear and unambiguous; if it's not clear and unambiguous to fellow experts, then they can't use it without risk.

Not Playing to the Gallery

The last two items are in some ways the most revealing of how different science is to other institutions. Consider a lawyer addressing a jury – the job of the lawyer is to convince a lay jury of guilt or innocence – or consider a politician addressing ordinary citizens. But if one finds a fellow scientist with whom one has a disagreement addressing a lay audience rather than you, the expert, it is a shocking experience – one that I have encountered when debating fellow social scientists. The job of a scientist is to convince other experts and to do that one has to start from the other experts' position; a scientist addressing a lay audience in the manner of a lawyer or a politician will find it more convenient to ignore the opposing expert's position or even to provide a distorted version of it – which is hopeless if you want to convince the fellow expert in the quest for correspondence truth. Finding one's fellow scientists playing to the gallery is awful. The final item is even more revealing. It's nicely captured in the lyric from the ABBA song 'Waterloo' – 'I feel that I win when I lose'. A scientist discovering that they are clearly and unambiguously wrong about something can be nearly as pleased as when they discover they are right about something – discovering you are wrong takes you in the direction of

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correspondence truth and that is pleasing because that's what your life is about. Compare this with a lawyer, whose job is to do their best for their client irrespective of the actuality, or a politician for whom being wrong about something has no imaginable advantage, or a businessperson, whose job is to make money pretty much irrespective of any deeper truth.

In sum, the reason science has a special place in democracy is that in so far as democracies have to make decisions that turn on the observable world, it is scientists who have the best skills and the social organisation to discover the nature of the observable world. Still more important, science is invested with truth more obsessively than any other institution and truth is vital to all decision-making, including decision-making under uncertainty. Therefore, even though science cannot claim the perfection it was thought to have 'once upon a time', it is still the way to bet and an object lesson for all decision-making even when the speed of politics is faster than the speed of scientific certainty-making.

An example: MMR

An episode of public engagement with science that illustrates some of the points we are trying to make is the widespread revolt against measles, mumps and rubella (MMR) vaccine that began in the 1990s and continues to this day to a lesser extent. It is widely agreed that the consequence of this revolt has been an increase in measles epidemics across various countries because the level of vaccination, while still around 85%, has dropped to the point where herd immunity has been lost and measles can spread; here, immunity requires around 95% of the population to be vaccinated. The spread of measles is serious: it is a dangerous disease that can lead to maiming and death in a small number. Notably at risk are children with a compromised immune system who cannot be vaccinated and therefore are specially at risk from communicable disease.

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The story of the revolt is well-known. It was begun by a medical doctor, Andrew Wakefield, who published an article in *The Lancet* reporting some observations that purportedly linked autism with measles virus in the gut of affected children. Somehow this became parlayed into a story about MMR being a cause of autism. This was especially strange since Wakefield continued to support the use of the single-shot measles vaccine which, in the absence of evidence in addition to the presence of measles virus in the gut, one would have thought, would be at least as dangerous. Sometime later, it was discovered that Wakefield had a financial interest in the single-shot vaccine. *The Lancet* article was eventually retracted but not for 12 years but, in any case, that article does not prove anything much – the numbers were very small, and the link with MMR as opposed to measles vaccination was not shown but appears to have been promulgated through interviews with Wakefield.

There are a number of suspect actions in this episode. It is not clear why *The Lancet* published the article in the first place, although some well-known science journals are spoken of among the science community as favouring newsworthy findings that are more likely to be subject to retraction. In the UK, certain Conservative Party politicians could be heard on the radio favouring parental choice in respect of the vaccines their children received and asking for the option of single-shot vaccines to be available for those who wanted them in place of the combined MMR vaccine. Stories circulated that suggested that a combined vaccine like MMR overwhelmed a child's immune system. On the other side, epidemiologists insisted that single shots would result in missed vaccinations and delayed vaccinations, endangering the maintenance of herd immunity. Epidemiological studies also showed that there had been no increase in the incidence of autism in countries that had newly introduced the MMR vaccine.

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Parents and carers were placed in a very difficult position. It was a statistical inevitability that a number of children started to show symptoms of autism shortly after vaccination with MMR – autism typically reveals itself around the age of vaccination. For a parent or carer this coincidence must have been emotionally devastating and was overwhelmingly likely to be read as a causal sequence. What such carers were not in a position to see was that there would be a roughly equal number of children who started to show autistic symptoms just before the vaccination, cancelling out the causal impression – but this must have been the case given the result of epidemiological studies.

The newspapers and other mass media played a damaging role in the revolt because many of them followed the journalistic norm of trying to present ‘balanced stories’ which set a carer’s experience alongside the views of epidemiologists and medical specialists, as though these were equal and competing opinions. This, effectively, hugely increased the credibility of the link between vaccine and autism, whereas the epidemiological and medical expertise should have been given overwhelmingly more weight.

Conclusions re MMR

The MMR story perfectly illustrates why the statement by JFK Jnr quoted above is so wrong-headed. Ordinary people are not in a position to make informed judgements about technical matters any more than they are in a position to do their own plumbing, electrical work, or car repairs: they do not have the knowledge or skills. The only kinds of evidence that bears on the question of whether MMR causes autism are statistical and medical, and ordinary people don’t have access to this evidence except through well-thought-out meta-expertise. Nor do Presidents of the United States, the latest of whom said this in a speech at the White House on 22 September 2025, referring to RFK Jnr:

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I want to thank the man who brought this issue to the forefront of American politics along with me, and we actually met in my office, is it like 20 years ago, Bobby? It's probably 20 years ago, in New York. I was a developer, as you probably heard, and I always had very strong feelings about autism and how it happened and where it came from.

And he and I -- I don't know. The word got out and I wouldn't say that people were very understanding of where we were, but it's turning out that we understood a lot more than a lot of people who studied it, we think. And I say we think because I don't think they were really letting the public know what they knew.

Among the things that the President went on to complain about, at this time when medical specialists were desperately trying to raise the vaccination level to re-establish herd immunity, was the following:

And they pump so much stuff into those beautiful little babies, it's a disgrace. I don't see it. I think it's very bad. They're pumping -- it looks like they're pumping into a horse. You have a little child, a little fragile child and you get a vat of 80 different vaccines, I guess, 80 different blends and they pump it in. So ideally, a woman won't take Tylenol.

And on the vaccines, it would be good instead of one visit where they pump the baby, load it up with stuff, you'll do it over a period of four times or five times. I mean, I've been so into this issue for so many years just because I couldn't understand how a thing like this could happen and you know it's artificially induced.

... The MMR, I think should be taken separately. This is based on what I feel. The mumps, measles and the three should be taken separately. And it seems to be that when you mix them, there could be a problem. So, there's no downside in taking them separately. In fact, they think

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it's better. [He appears to be saying, 'I may not know much about medicine but I know what I like'.]

But science journalists should have had the scientific and statistical skills to read *The Lancet* article and work out that it was scientifically close to worthless and unmeasurably far from establishing the harmfulness of the combined vaccine, and this could have been done long before it was discovered that the author was standing to benefit financially from the causal claim. If you're reading this paper and you come from the sciences you should be easily able to see that if you get hold of a copy of *The Lancet* paper. But the proof of the opposite is a matter of epidemiology – the fact that autism rates don't increase where MMR is newly introduced.

Furthermore, the matter of herd immunity is quintessentially a matter of statistics. Only those who can know vaccination rates across a community and know the statistics of herd immunity have the ability to understand what is going on. The carer exercising their 'right' not to vaccinate has no way of knowing how exercising that right will affect the children of other parents because it depends on what other parents do. The economic phenomenon is known as 'the tragedy of the commons' – since all vaccinations are marginally risky it is in everyone's interest not to vaccinate in the hope that everyone else will vaccinate and protect them from the disease via herd immunity. But if a large enough number act in a narrowly self-interested way there will be no herd immunity and everyone's children will be in danger of diseases such as measles, and we might even see the return of diseases like polio: the most narrowly self-interested action leads to the most self-damaging outcome.

Supported by the banner of freedom, people have enormously strong feelings about what follows from this. People feel that they should be free to decide for themselves whether to vaccinate their children given that – and we must accept this – vaccination always carries with it a very small risk. But that risk

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is almost infinitely smaller than that associated with the disease the vaccine protects against otherwise the vaccine would not be certified for use. As I learned from an American libertarian friend of mine, freedom is never an unqualified right. As she put it, quoting something that goes back 150 years or so ‘your freedom stops at the end of my nose’. Which is to say ‘You’re free to act as you wish, until your actions harm someone else.’ Refusing to vaccinate harms me and my children as well as you and your children because of the way it erodes herd immunity. And, if my child is immune-compromised, I cannot protect them from your actions by vaccinating them. We should no more demand freedom about whether to vaccinate or not as a right, than we should demand freedom to drive on whichever side of the road we prefer: if you value the health of your children and others’ children, whether or not to vaccinate has to be a collective decision based in scientific authority. But if you still prefer your freedom to endanger others’ children, as well as your own, then that’s a choice that belongs to a moral code with which I am unfamiliar.