Observations on the Foundations of Infodemiology

Peter Bernard Ladkin

Causalis Ingenieurgesellschaft

Bielefeld, Germany

Abstract *Infodemiology is a new subject, or rather an old subject with new relevance, named by the World Health Organisation. It is concerned with the dissemination of accurate information, as well as the identification and correction of inaccurate information, concerning health. Early on in the 2020 Covid-19 pandemic the WHO judged infodemiology to be an important part of countering the pandemic. Its foundations are old, involving epistemology, and raising such questions as what is good science, and even what is truth. I consider some aspects in detail.*

1 Introduction

The World Health Organisation has noted a problem with information coursing throughout the world about the Covid-19 pandemic, and that much of it is misleading, poor, even dangerous. WHO coined the term "*infodemic*" for this phenomenon and convened the first symposium on "*infodemiology*" (WHO 2020)

The Forum on Information and Democracy convened a Working Group on Infodemics (FID 2020-1) which produced its first report, on a policy framework, in November 2020 (FID 2020-2). The members of the International Commission on Information and Democracy are listed in the report. There are some well-known names. 38 countries are said to have signed up already to the charter International Partnership on Information and Democracy. The report is concerned straightforwardly with information and misinformation, the current role and potential future role of communications channels such as social media, and so on.

There are some general "infodemiological" issues about which people are concerned, such as

- there is a lot of false and misleading information about Covid-19 in the public or semi-public domain;

- this information is propagated in ways which have only recently become available, to individuals and group via "social media";

- there thus develop largish geographically-distributed groups of the "like-minded", who believe certain propositions, such as that Covid-19 is made dangerous through electromagnetic radiation from 5G communication networks, or that Covid-19 is largely a hoax (it has been noted by many that these two propositions are contradictory, but many so-called "Covid resisters" apparently claim to believe both). The first leads to resistance to a benign communications technology of potential great benefit, and (as in the UK) significant damage to property, as people try to destroy 5G communications towers. The second leads to nonchalance about the public health measures needed to get and keep R_t below 1, and thus limits their potential effectiveness;

- there is less absurd, plausible but wrong, information making the rounds, which, if believed, could hinder the most effective dampening mechanisms, such as that one can only contract "severe Covid" if one has "underlying health problems", even if not yet identified (e.g., heart disease or heart weakness of some sort, or a metabolic imbalance or weakness, or a compromised immune system). Such a belief could lead people who think they are "healthy" to be as nonchalant about Covid prophylactic measures as they are about catching a cold or influenza, and if large portions of the populace are nonchalant, it is hard effectively to execute public health measures that will attain and maintain R_t below 1.

Rather than addressed these issues directly, I concern myself here with some foundational issues with which many informaticians and budding infodemiologists might not be familiar.

2 Infodemiology by Example

A recent Viewpoint article in the Journal of the American Medical Association by Bruce Miller, a UCSF neurologist (Miller 2020), deals with the very real problem of "*science denial*". This paper is surely a contribution to infodemiology.

Proponents of science (including myself and likely Miller) would like to say that science is a series of reliable ways of coming to knowledge about the world. However, some people might be surprised to learn that the question of what science is, and how it can be distinguished from non-science or bogus science, is a difficult question to answer. It is safe to say this question has not been adequately answered to date.

First, concerning reliable ways of coming to knowledge about the world, there are three points where such a potential definition trips up: "the world"; "knowledge"; and "reliable". If knowledge is thought of in some way as justified true belief, which it has been in many epistemological investigations in the 20th century[1], then three further questions arise as to what a belief is, how it may count as "true", and what could justify it. In these conceptions, the notions of "justified" and "reliable" are likely related, as are "true" and "the world". A belief is justified if it is reliable, or maybe one would prefer to say it is reliable if it is justified. Surely, one might wish to say, an assertion is true just in case it describes the world as it is – the so-called correspondence theory of truth (David 2015). But what is "the world"? Wiggenstein famously said in Tractatus Logico-Philosophicus (Wittgenstein 1921), Proposition 1, "*The world is all that is the case.*" He followed it up with "*1.1 The world is the totality of facts, ...*" Rather than a bunch of facts, many of us are likely to conceive of "the world" as consisting rather of a collection of interacting things, both inside and outside our front door, and including us ourselves. But Wittgenstein continues Proposition 1.1 with: "*... not of things.*" So much for things chez Wittgenstein. Was he just wrong?

And so it goes on. The Tractatus was published 100 years ago this year. Infodemiologists should not need to become philosophers of science, but it will surely help to realise that there does not appear (yet?) to be a well-principled division into "knowledge/bogus knowledge" and/or "justified belief/misplaced belief" and it can be hard to navigate those lines of reasoning which may lead to epistemic scepticism.

[1]See, for example, (Phillips Griffiths 1967). The conception of knowledge as justified true belief was famously brought into question by Edmund L. Gettier in his exceedingly short paper (Gettier 1963). Nevertheless, this does not rule out a practical conception of knowledge as *appropriately* justified true belief. The question not addressed by this characterisation is what counts as "appropriate".

Second, much, even most, of the knowledge we scientists have about the world is taken on some level of trust from somewhere. I think dexamethasone helps somewhat with severe Covid-19 because the RECOVERY trial said so and wrote it up in a renowned journal (RECOVERY 2020-1) Whereas other organisations and document collections will (attempt to) show me that MMR vaccines cause autism. I believe the firs,t and reject the second, not because of detailed first-hand knowledge I have of severe Covid-19, dexamethasone, MMR vaccines, or autism, because I don't have any at this point. But I do epistemically trust the Recovery trial and the New England Journal of Medicine, and I don't trust the sources that say that MMR vaccination causes autism.

There are networks of trust. I am in one (which believes the RECOVERY results), and am staying away from another (which tries to relate MMR vaccine with autism). How do these networks work? Are some of them “valid” or “reliable” in some sense, and others “invalid” and “unreliable”? I would say my trust in Recovery and NEJM is justified, but how is that justification built and how does it not apply to the MMR/autism constellation?

Third, we may think there are facts, and that there are, separately, values/evaluations. The facts about the wine in this glass include its color, aroma, chemical constitution, and the values include its deep berry fruitiness, hint of sweetness, suppressed tannins, and quaffability. Those latter are relative to my sense of taste and other perceptions, but are they not equally factual? We think ourselves able to distinguish fact from evaluation. But in medicine (and not just in medicine) they turn out to be almost inextricably intertwined, while still being different. I give below an example of a case in which the facts are pretty much agreed, but the evaluation of those facts is radically different. Making our way around fact/evaluation constellations is not easy.

I focus on these three characteristics in more detail below.

The general issue around “science” is, in any case, wider than the specific phenomenon which Miller addresses, the evaluation of facts under conditions of cognitive weakness. It might be well to indicate how. Two additional phenomena important for infodemiology are, first, that there is general social use of the term “science” to stand for “something I want you to take as fact and not to question, and which has been proposed by people who describe themselves are scientists”; second, there are of course mistaken claims made about "science". My second and third examples incorporate these phenomena.

My second example. Does hydroxychloroquine help patients with any of the stages of Covid-19? Is it useful prophylaxis? Politicians on the world stage have proffered opinions. But isn't this simply a question which can be answered (if we will) by the medical-scientific establishment? Yes, it is, and it has been. The trouble is – answered in two contradictory ways.

Didier Raoult, a celebrated doctor and academic in Marseille, promoted hydroxychloroquine as an anti-Covid-19 medication in March 2020, was visited by the French President Macron in April, and is now having to defend his support for the drug before a committee of his peers (Agence France-Presse 2020).

The newspaper quote is telling:

> *A French professor who touts the anti-malaria drug hydroxychloroquine as a coronavirus treatment – without evidence, scientists say – will appear before a disciplinary panel charged with ethics breaches*

"….[S]cientists say" – but he is evidently one, and he presumably does not think there is "*no evidence*" in the peer-reviewed paper he and his collaborators published in July 2020 (Gautret et al 2020) I doubt those collaborators think that, and I doubt the reviewers of the paper do. The publisher is one of the main highly-respected medical-scientific publishers. If "*scientists say*" there is no evidence, then what does all that writing in the paper constitute, if not evidence? (Or is the claim rather that the authors are not scientists?)

There have since been RCTs and other observational studies as well as metastudies which have almost uniformly come to the conclusion that hydroxycholoroquine has no statistically significant effect on the progress of Covid-19. One is from the very well regarded RECOVERY trial (RECOVERY 2020-2) run out of the University of Oxford.

The politico-social problem which lands Professor Raoult before a committee of his peers seems to be that he has continued to promote the drug after the results of the RCTs and other trials which contradict what he claimed in March and published in June.

So what in fact does "the (established) science say"? It says two things: first, 80 or so people in Marseille with Covid-19 seemed to have been helped by being given hydroxychloroquine. Second, hydroxychloroquine showed no significant benefits for Covid-19 treatment in a large cohort in a number of RCTs. These are not contradictory statements as such, but one is surely a contraindication of the other.

Is Professor Raoult committing "science denial" if he says that, whatever the result of the RCTs, he has seen people helped, and written up his observations? No, he is thereby "doing science" – which does not preclude him being wrong about his claim of general benefit.

To return to Miller for a moment, can we imagine any way of sorting this situation out in order to present it to people who may have the kinds of cognitive weaknesses he highlights?

This is my best guess as to what will happen. There is a negotiation to be had between two scientific cohorts. It has been undertaken, or will be undertaken, because that is one of the ways medical science gets done. I anticipate that it will be resolved in favour of the RCTs and metastudies, because well-run RCTs are regarded in medicine as the most reliable epistemiological methods and smallish observational studies such as those of Raoult come a very distant second, and this for well rehearsed reasons. One subtext of the French inquiry might well be that he is raising an observational study above a well-conducted RCT, and some of his peers may think this is inappropriate (I have no comment to make on such a possible view).

To connect this issue directly with the worries that led to the inception of infodemiology, I mention the threats received by a researcher after a Brazilian study of chloroquine in treatment of Covid-19 was published in preprint, as recounted in (Ektorp 2020). Apparently the threat reduced after the study was published in the J. Am. Med. Assn. It is puzzling why that should be – verbally-violent bullies are not generally known to defer to the respectable medical literature. Similar hostility has apparently been shown on social media towards the authors of a Swiss metastudy of hydroxychloroquine for Covid-19, as reported by (Peiffer-Smadja et al 2020) after the publication of their metaanalysis on 2020-08-26. Both studies showed the drugs concerned did not exhibit statistically significant therapeutic effects in Covid-19 treatments.

Lots of people recognise there are different scientific sides to many medical questions. But here, as my third example, is an occurrence of it being invoked dubiously, from the daily live blog on Coronavirus run by The Guardian newspaper on 2020-11-18 (Guardian Coronavirus Live Blog 2020):

> *In Iowa, Governor Kim Reynolds had pushed back against a mask mandate for months but imposed a limited one Tuesday, ... At the same time, she claimed "there's science on both sides" about whether masks reduce the spread of the coronavirus.*

It seems that Governor Reynolds is claiming that medical science is undecided about the use of everyday masks in everyday tasks – e.g., shopping, sharing public spaces such as parks and public transport with unknown others. But it is not undecided in the top medical-scientific literature. There are, rather, articles about why the advantages of mask-wearing are not being generally accepted (Peeples 2020). After months of discussion, and many articles in the reputable medical-scientific literature, as well as advice from the US Centers for Disease Control and Prevention (CDC 2020), there is science and common sense on one side of the argument, and inconvenience, but certainly nothing amounting to much science, on the other. So is this a mistake by Governor Reynolds, or is it rather a misuse of the term "science" when she could more accurately have said "opinion"?

We can see a number of issues here that by their nature are fundamental to infodemiology. What is "science"? How do you tell if something is "science"? What does "science say"? In particular, when "scientists" come to contradictory partial understandings of a phenomenon, which they often do, how are these resolved into what "science says"? If "science" says X, and "science" says (somewhere else) NOT-X, do either or both of these statements constitute "science denial"? (Note that each of them is contradicting "science", as given by the other.)

I consider in more detail below:

- what counts as science? (And what do we do when "science" is contradictory?)
- how do I come to attain and trust in what I think of as my knowledge, specifically of scientific fact?
- how do I distinguish – can I distinguish – between "fact" and evaluation?

3 Miller and "Science Denial"

Miller is mostly concerned with obvious examples of misleading beliefs, such as the belief that Covid-19 is a hoax, that there is no such illness; and that Covid-19 is no worse than influenza. Some people apparently believe these contentions, despite a plethora of evidence carried in most reputable news sources about CoViD-19, including "press releases" and other information from the WHO, from national public-health organisations, from the medical-science literature and articles in reputable newspapers. Such people explain the different information as a "conspiracy" by elites (such as government and newspapers) to provide misleading, deliberately frightening information, whereas the "reality" is benign. Miller explains some brain-physiological phenomena which can cause people to develop and strongly maintain strange beliefs.

Miller notes that, with a lack of education in basic tools of science such as graphical information, it can be hard for people to interpret scientific information presented to them in public health/medical-institute press releases and in news media. Such people thus revert to explanations which they can more easily assimilate, which can often include conspiracy theories. Two examples of conspiracy theories around Covid-19 are (my examples; Miller does not discuss them in depth):

- Covid-19 is a hoax, perpetrated by some power elite in order to achieve a social transformation which will benefit them;
- Covid-19 and SARS-CoV-2 are real, but they were deliberately engineered by some elite in order to profit from the consequences.

Miller proposes that the "*medical community mount systematic efforts around science education beginning in childhood and across the lifetime.*" He has some good suggestions about accessibility of information, both in terms of content and in terms of availability. All good stuff.

But…...

- "Science denialism" is not an illness, although some forms of odd belief can indeed be correlated with illness, as Miller points out.

- A key component of anyone's beliefs about "the world" out there are hisher human networks of (epistemic) trust. How do most of us, including scientists, get the "right" information about something (most things) of which we do not possess personal, phenomenological, first-hand evidence?

- Even given a similar, even identical epistemic context (same info, from the same network of trust), people may value the information differently, and draw different conclusions from it.

When differing views on the epistemic nature of science are in play; when radically different networks of trust are involved (someone's group of correspondents on Facebook, rather than WHO press releases); when very different valuations of the same material are possible, I suggest it will not suffice "to get your message across better". We need in addition to discuss valuation criteria, the configuration of networks of epistemic trust, and ultimately the epistemic status of medical science.

4 "Science Denialism" is not an Illness

Indeed, it is a/many well-established philosophical position/s.

The issue of how and why science "works", if it does work, has been thoroughly discussed in the philosophy of science for centuries. I have a shelf full of books by eminent scholars querying whether there is any such thing as "truth", and thereby "facts", whether these are or are not necessarily relative to some personal or social belief systems. Quine's "Web of Belief" (Quine and Ullian 1978), Rorty's strong and well-maintained denial that there is such a thing as "truth", e.g. (Rorty 1979), Nozick's extended identificationof phenomena to which notions of truth or objectivity are relative (Nozick 2001). The entire US tradition of "pragmatism" (Legg 2020), by means of which truths are those propositions which it is somehow convenient for us all to believe or agree on (Glazberg 2018) and there is no other criterion (such as "correspondence with reality, or with the world").

These issues are not just for academic philosophers. There have been controversies in the US for over a century about Darwinism and Creationism; whether biological evolution is a fact and whether that is how we got here; whether Lyell's geological time frame is real, or whether it was just deliberately made to look that way when the earth was (supposedly) created 5,000 years ago. Those supporting so-called Intelligent Design (Intelligent Design Creationism) have considered these issues technically (Dembski 1998). There is a non-trivial amount of belief in young-earth creationism in the US population (Wikipedia Evolution, no date). So, if one is to follow Miller's suggestion and improve science teaching in the US, there is an unresolved issue of exactly which set of facts teachers are going to present as "science" and which as "not science".

When I was teaching in the 1980's at California State University, Hayward, I had a charming office mate who became a close friend. She was a biblical literalist. She also had worked as a researcher in biology labs, where of course she had to assume biological evolution and indeed had seen it working in fruit fly populations, as I recall. She was quite successful, but preferred to teach math. I asked her how she reconciled the two: biological evolution with young-earth creationism. She said that biological evolution was the way to advance the science of biology; she had no difficulty with assuming it in that context. Whatever the reason for it (and there must be a reason – all features of the world were teleological to this view), it was necessary. So of course she assumed it. And the Bible is literally true when talking about the creation of the world. I had not before encountered such a thorough-going practical pragmatism (in the philosophical sense). I am out of touch with her now, so have no idea what she thinks of CoViD-19.

Someone holding views similar to Miller might reply: yes, but she accepted the science: that is what counts. Well, she did and she didn't. As a routine biologist, she accepted the routine biology. But a new pandemic such as CoViD-19 throws up all kinds of uncertainty and is anything but routine. When it comes to taking a bet on what's right and what's wrong, and what to do, it is quite plausible that a belief in an omniscient omnipotent being who promotes the ultimate welfare of humankind (although not necessarily the day-to-day welfare) leads one to a different guess as to what to do than does a belief that this disease could just wipe us all out if we are not careful. Which counts as "science"? Which do we teach our kids right now in the schools, according to Miller's suggestion? I don't think there is a simple answer.

Consider quantum mechanics. There are many physicists, Einstein amongst them, who think or have thought that quantum mechanics is a flawed scientific theory, for generally two reasons:

- it treats its objects in one of two mutually contradictory ways: as a particle, or as a wave, and one cannot say in advance in any given situation which;

- it is inherently probabilistic; phenomena manifest themselves spontaneously according to probabilistic regularities: poof! here is a particle-antiparticle pair, and poof! now no more. Einstein is reputed to have remarked, in a letter to Max Born, “God does not play dice with the universe.”

However, even if people profoundly disagree on the ontological basis of quantum mechanics, there is no disagreement amongst practitioners that it is one of the most successful predictive theories in science. Whatever you think of its foundations, if you are doing physics you need to use quantum-mechanical calculations where applicable. This seems to me to be exactly parallel to the situation in which my young-earth-fundamentalist biological-research colleague found herself. She knew that the method you had to use – evolutionary reasoning – contradicted her beliefs. She used it anyway. A physicist using quantum mechanics knows that the method she has to use apparently uses contradictory ontologies. She uses it anyway. A pragmatic (in the informal sense) approach.

5 The Issue of “Alternative Medicine”

In medical science, there is a notorious movement, or series of movements, which have been branded, amongst other provocative titles, “science denial”. It is, of course, homeopathy. I briefly review pro's and cons. There are some nutty “alternative medical” principles; those will not concern me here. I consider two main superficially-reasonable principles of homeopathic medical treatment:

- Water has a memory of substances that were dissolved in it. Unlike the substances themselves, this memory is pervasive in the water sample, and has causal efficacy. This causal efficacy is often (but not invariably) to stimulate the body's resistance to certain illnesses in certain ways. This is what “homeopathic drugs” are: water with memory.

- An illness or medical problem manifests in a certain way, but is rarely treatable in isolation. An entire conception of body+mind must be constructed, a holistic conception, in order to find the most efficacious way in which the presenting problem may be mitigated

It is obvious that these principles are only applicable in certain regimes of medical help, mainly biochemical. They are not going to help with trauma. If you broke your arm, you primarily need it set, and pain and other discomfort controlled, until the bones fuse back. Water memory doesn't come into it. Although the second principle might. Say, this is the third time in three years you've broken bones. A curious health practitioner might wonder why. It turns out you're an alcoholic, get quite drunk a lot of the time, and fall down stairs. Only a “holistic conception”, one that mitigates your alcoholism and habitual drunkenness, is likely to save you more broken bones.

The hypothesis of water memory is dismissed by most, but not all, scientists. Notably the Nobel Prize winning physicist Brian Josephson (Wikipedia Josephson, no date) has worked on it. He is by no means the only capable scientist to have done so. I have nothing further to say about water memory, except that I personally do not believe such homeopathic drugs have any causal biochemical effects, except to hydrate you a little more.

However, the holistic approach to illness has more than a little merit. The human body+mind is a tightly-coupled, interactively complex system, as the late Charles Perrow might have said. When such systems are going wrong, they are not to be understood well in a ten-minute interview with a doctor. Medical practitioners understand this, of course, indeed diagnosis is a major, if not the major, general medical skill.

But the holistic approach, according to some, of whom I am one, goes overboard in homeopathic treatment. Each person is an individual body+mind system, with individual checks and balances. Each biochemical intervention has effects on the entire system which are reasonably to be expected to be different for each individual. According to this conception, you thus cannot localise the effects of biochemical interventions. It follows that randomised controlled trials (RCT) of drugs cannot yield useful information, as they look for system-localised effects and there generally aren't any meaningful purely-localised effects. When you perform an RCT, according to this view, you are thus looking for a chimera – the best you can do is observational cohort studies.

I don't believe that line of reasoning, and neither do most medical scientists. RCTs are the “gold standard” for demonstrating the biochemical efficacy of a drug, for well-rehearsed reasons. I accept and value those reasons highly. But we can also recognise there are regimes in which RCTs are hard or impossible, even unethical, because potential controls are so ill, and there is prima facie evidence from cohorts that a given drug alleviates their illness, that one cannot humanly assign a patient as a control. And it is physically impossible to perform, for example, a double-blind trial of acupuncture.

Enough said about (rational reconstructions of) “alternative medicine”. The take-away points are that it[2] has substantial adherents throughout almost all the world; those adherents are unlikely to reduce much in number during the course of, say, a pandemic; and the general (defensible) principles of alternative medicine conflict with some of those of “establishment” medicine. This situation must be recognised and accommodated in infodemiology – by the adherents of “alternative medicine” just as much as by “establishment” medicine. One cannot just ignore such a substantial phenomenon.

6 The Social Psychology of Belief

[2]It may be misleading to take the various alternative medicines as a cohesive whole. Nevertheless, I use the singular pronoun.

The Coherence of (Some) Conspiracy Theories, and Networks of Trust

Much or most of the stuff we think we know is content which we have accepted at some point in our lives on some sort of trust. Is Fermat's Last Theorem really true? Sure, Sir Andrew Wiles proved it. Did he prove it? How do I know he proved it? Am I even capable of checking?

The answer to this last question, quite literally, is that I do not know whether I am capable of checking – there is a bunch of esoteric math in there with which I am not in the least familiar. Very, very few people in the world are so familiar. In the absence of (a means of) directly checking, I nevertheless do believe Fermat's Last Theorem is true and that Wiles proved it. The reason I believe it is through a chain of trust in my mathematical colleagues. The guy who photographed Wiles's original non-announcement (he reportedly just left it hanging at the end of a lecture) is Berkeley's Ken Ribet (there are pictures on the WWW, e.g., (Singh, no date), but not Professor Ribet's). I worked in the department where Ken Ribet works. I may even have seen Wiles in the Math Common Room on a visit. I never talked to Professor Ribet about math, but I knew lots of people who did, who knew his work and his professional attitudes from daily contact, and who worked at some level with him. When he suggests that it looks as if Andrew Wiles has done it, then I am very likely to trust that, indeed, it looks very likely that Wiles has done it (in fact, he hadn't. There was a gap that needed to be filled, as it was a year or so later by Wiles and Taylor). There is a whole social network of trust and belief that is involved in me, personally, believing that Wiles (with Taylor) has proved Fermat's Last Theorem. I trust the epistemic judgement of my former acquaintances in the Berkeley Math Department. I trust the Berkeley Math Department with respect to math. And so on.

A lot of science is now like this. The science itself has become so involved that largely only the specialists are able to grok it. I don't know how Crispr-Cas9 works. I do know what certain publications such as Scientific American tell me about how it works. I trust Scientific American and its authors and editors (at least some way; it is not that they don't make mistakes occasionally). I trust J. Am. Med. Assn. (which is why I am reading its Covid coverage) and its editors and I trust Miller's article. But only to the extent that I can see why I disagree with his diagnosis of "science denial" and his proposal to mitigate it.

Furthermore, some of these conspiracy theories that Miller is targeting are not implausible per se. One of them I have read is that Bill Gates had associates develop SARS-CoV-2 and unleashed it upon the world in order to get richer than he already is. It is not prima facie implausible that rich, wealthy and capable people and organisations attempt to do things which benefit themselves but harm others; the history of oil drilling in Nigeria, for example, or the atomic bomb testing on Pacific islands.

There are many such examples. But is this one? I met Mr. Gates once, when he exhibited Xenix running on an LSI-11 to the Unix User Group conference in Santa Monica in 1979. I met him briefly, and others I knew knew him already. As an informatician, I have regularly read newspaper reports of what Microsoft and Mr. Gates are doing, so my picture of him has been continually updated for over 40 years. Mr. Gates has (to my mind) unimaginable wealth, but what little I think I might know of him conforms with the impression I got from the guy I met in Santa Monica.

For some decades, I have read how Bill and Melinda Gates are now using their wealth in various ways to support the general human good, via the Bill and Melinda Gates Foundation for world health care. They are philanthropists. They are apparently giving their wealth away to worthy causes, and have been for decades. I also know people who know them, or people who know people who know them, more or less continuously since 1979. The story coming from those acquaintances is entirely consistent – that is indeed what they do. The idea that they are trying to make money hand over fist from a pandemic clashes starkly with that impression developed over decades. I thus find the conspiracy theory utterly implausible. But I have a rich information context to which I can refer, that a boy, say, growing up on a Texas ranch with the nearest neighbours 20 miles away and getting news from (to my mind) biased TV programs, does not necessarily have. I am less susceptible to such a conspiracy theory than he may be.

Let us extend the example. The Chinese had a number of SARS-CoV-2 vaccine candidates interestingly quickly to hand as the pandemic developed, as did the the US (in cooperation with companies in other nations). Could it have been that some technically-capable government and its subsidiary labs either concocted a virus, or isolated one (as well as lots of others) from bats and other wild creatures, and tried it out (along with lots of others) on small groups of unsuspecting civilians? Such experiments have been performed on unsuspecting human populations before; the 40-year Tuskegee syphilis study (CDC, no date), for example. The consequences and advantages of trying it would be various and might be politically tempting to some: one could imagine quickly “saving” one's own population with a vaccine, and watch one's rival countries struggle to cope, offering “help” (some of your vaccine) to widen one's influence amongst the more desperate nations of the world. And/or one could make tons of money selling one's advanced vaccine (which is likely to be first or near-first to market).

This is not a nutcase theory. There are historical examples of fragments of this story happening. I happen to think such a deliberate-CoViD-19 story is wrong. I read the newspapers; I read the accounts of journalists with good reputations who talked to people close to the originating events of the pandemic, for example, the AP reconstruction (Associated Press 2020); I assess them for plausibility.

For example, scientists with good reputations tell journalists that it is moderately easy to tell if a genome has been intentionally modified by humans, as we used to be able to tell if a digital photograph had been "doctored"; these reports appear in reputable newspapers and are not contradicted by other scientists with good reputations. Because of this, I take it to be that the SARS-CoV-2 virus is natural and has not been artificially enhanced. Do I know this/can I know this first-hand? No. I don't know enough genomics and microbiology and do not have the experience, even if it was all laid out before me. I am epistemically trusting.

I currently believe that SARS-CoV-2 is an accident of nature, as AP described it[3]. Presumably if the Chinese government aids the WHO and associates with forensics it will be demonstrated to my satisfaction and yours, dear reader, that SARS-CoV-2 is an accident of nature. But the conjecture of deliberate progeniture is at this point not a nutcase conjecture; it is exceptionally unlikely, as argued above, to the point at which I reject it. However, the deliberate testing and spreading of a natural virus, as a form of biological-warfare-research or as an attempt to make profit and buy influence through distribution of a vaccine, has not to my mind been conclusively refuted. I would not at all be surprised to find that a fair amount of effort by various national intelligence services has been spent in looking at this possibility over the last nine to ten months. What is quite certain is that such a theory has little to do with dementia with Lewy bodies or frontotemporal dementia, the physiological conditions in which Miller tells us false beliefs are common.

What do you do if you are one of those Americans who doesn't read a newspaper, and cannot necessarily analyse or interpret a story in it if they do? Many US regional newspapers are full of bare-bones opinion masquerading as "news" (whereas the top US newspapers, such as the NYT, have devised ways of reporting which separate fact from opinion much more clearly than, say, British newspapers). Where do such people pick up their beliefs? Like the rest of us, from their networks of trust. If their networks of trust do not include the NYT, Scientific American, and JAMA, NEJM, The Lancet, and the pronouncements of the WHO, then by my standards, and presumably those of Miller, they are left somewhat less well informed on CoViD-19 than I am or he is.

[3]This does not rule out that there are surprises in store. (Amendola et al 2021) describe identification of SARS-CoV-2 in a swab taken from a 4 year old child in Milan in early December 2019. (La Rosa et al 2021) describe identification of SARS-CoV-2 in wastewater in Milan in mid-December 2019 (also in Bologna end-January 2020 but by then there had been known Covid-19 cases in Europe). It seems to be that SARS-CoV-2 was circulating in distinct geographical regions in Italy well before the first case of Covid-19 was identified.

What happens if such a person looks at the ownership chains of all those organs and notices, correctly, that there is an elite involved. Harvard, Yale, Berkeley, Stanford, Oxford, lots of rich people. Telling us what to do and think as usual. Why? For *their* reasons. (Indeed so. And I am one of them.) Such a reaction is not necessarily irrational, especially not in any sense in which you might correlate it with physiology, and it cannot be mitigated by telling people they should just trust those elites anyway, even if you dress it up as "education". It is all about trusting and accepting certain types of authority, and, in that, the social phenomena concerning with trusting science and medical authorities have much in common with the movement around Black Lives Matter (trusting/not trusting the police if you are black), and other movements, such as "*draining the [U.S. government] swamp*", (trusting/not trusting the machinery of government and its lobbyists in Washington D.C.).

I have argued that we arrive at our preferred constellation of facts through our preferred networks of trust. But there are further differences when we have got there, namely in how different people evaluate arguments.

7 Differential Evaluation of Arguments

My colleague sees the existence of God as incontrovertibly proved; I see a quirk of logic.

Explaining the role of networks of trust is not the whole story. It does not explain all the differences which one may legitimately have with an interlocutor. One can have exactly the same networks of trust as another person, look at material in similar or exactly the same ways, but still come to a radically different evaluation. Here is the clearest recent example I know of extensive agreement on the content, but radical difference on the evaluation, of a subject matter/argument/story.

Somewhat over 900 years ago, Anselm of Canterbury proposed a proof of the existence of a supreme being, which we Westerners generally call God, with a capital "G". Anselm started from a description of this supreme being, as: a being greater than which it is not possible to conceive. This is a concept, an idea. He then went on to argue that such a being necessarily exists. Put crudely, if you think of God, s/he exists. Over the centuries, this argument has been discussed inter alia by Aquinas, Descartes, Leibniz, Kant, Hegel, Gödel and David Lewis. Most commentaries have concluded there are things wrong with it, and tried to say what those mistakes are. But Gödel came up with a version, presented to Dana Scott, who then published it more widely, which seemed to be logically correct. Versions of this argument have recently been implemented and checked in automated theorem provers. It is indeed right.

There is an extensive literature on the Ontological Argument. e.g., (Oppy 2018). It may well be the most scrutinised short argument in the history of ideas.

Very simple versions of the argument, using formal modal logic, were presented by Charles Hartshorne, who was born at the end of the nineteenth century and lived through the entire twentieth, and was a professor of philosophy at the University of Chicago, Emory University in Atlanta, and the University of Texas. His version was presented in (Hartshorne 1962)[4]. There has been a spate of recent automated proofs of various formal modal logical versions of the argument, including Hartshorne's (which is simple enough not to really need automated checking). John Rushby has recently shown, using the theorem prover PVS, how many recent variants reduce to Hartshorne's simple form or slight variants (Rushby 2020).

We may think some modal-logical argument right, but to some it might be gobbledy-gook. Quine argued famously that the foundations of modal logic were wobbly. He pointed out that, in contrast to classical (propositional and predicate) logic, terms in formal modal logics were not referentially transparent: you could not substitute equals for equals and retain validity (Quine 1953). The examples are simple:

- There are 9 planets (say);
- It follows that (the number of planets) = 9;
- Necessarily, 9 = 9. Written in the syntax of modal logic, in which the symbol for "necessarily" is $\Box$, $\Box(9 = 9)$;
- But it is not the case that $\Box$(the number of planets = 9).
- The last formula is obtained from the formula $\Box(9 = 9)$ by substituting the term "the number of planets" for the term "9".
- It follows by this example that you cannot always substitute equals for equals in a formal sentence of modal logic and retain validity.

[4]The relevant parts have been reprinted in many anthologies on the Ontological Argument.

Quine pointed this out in the 1950's and there have subsequently been many attempts to circumscribe this issue which have resulted in useful formal modal logics. However, this was not the only argument Quine mounted against the idea of necessity/"necessarily" as a coherent philosophical-logical concept. He compared Kant's analytic/synthetic distinction with the modalities (Quine 1951). For example, "a bachelor is an unmarried man" is true because of the meanings of the concepts in it; this is roughly what is meant by a proposition being "analytic"; if this is so, then necessarily a bachelor is an unmarried man – it simply cannot be otherwise. And so on. And Quine doubted that the analytic/synthetic distinction was coherent, on partly similar grounds by means of which he doubted the coherence of statements involving "necessarily". If you buy Quine's argument, the formal modal Ontological Argument is a non-starter, because you cannot coherently express its components.

This is all well-known to Martin Ward and myself. Martin is a colleague concerned, as I am, with software dependability. And he is also concerned, as I have been since I discovered it as a schoolboy in the 1960's, with the Ontological Argument in its various forms. We had a recent public discussion in the Risks Forum Digest (Ward et al 2020) (Ladkin and Neumann 2020). It seems to me to be the case that Martin and I have a similar technical view of the extensive literature on the Argument. However, whereas I consider Hartshorne's argument (and, according to Rushby, its recent logically correct variants) a simple, interesting quirk of logic, Martin thinks it a simple, obvious proof of God's existence and (to paraphrase him) that I should now be going to church on Sundays.

I am at a loss to reconcile these two quite different valuations of what I take to be the same body of intellectual material on which we seem to have the same views, apart from this valuation. But those valuations are what they are, and quite different from each other.

Consider a situation, maybe not quite so stark, with measures to inhibit transmission of CoViD-19 in enclosed spaces. There are certain facts, as well as certain possible or putative facts which we do not yet convincingly know. There are situations in which Covid-19 has apparently been transmitted to many by a single index case (superspreading events), in which neither precipitating droplets nor fomites appear to have played any significant role in transmission. Two such situations which have appeared in multiple studies are: a restaurant in Guangzhou (Lu et al 2020) (Li et al 2020), and a choir practice in Skagit Valley, Washington (Hamner et all 2020) (Miller et al 2020).

The plausible conclusion from these studies is that transmission was accomplished through inhalation of viable virions in aerosol form. This is a putative fact, very likely to be a fact. Virions remain viable in aerosols for up to 3 hours, with a half-life of around 1.1 hours (van Doremalen et al 2020). This is a fact. A complete air exchange in an enclosed space of six times per hour is thought to be enough to inhibit any transmission via aerosol (Spahn, Richter et al 2020). This is a putative fact, very likely to be a fact.

Now, here is a room, a school classroom; here are the windows. Here in the corner is a filtering air-cleaner which filters out particles of the size of SARS-CoV-2 virions. Opening the windows every ten minutes (to achieve some, but likely not complete, air exchange six times an hour) is impractical during lessons. Does opening the windows four times an hour, and using the filtering cleaner continuously, keep aerosols to a non-infectious level? That is an evaluation, given the information to hand.

The difference between this case and my initial example, concerning belief in a God, is that this evaluation could be addressed through the genesis of more facts; through measurements of the air circulation in this specific room, under the influence of the filter ventilator and regular window opening, and so on. It could become established as a fact that this regime suffices, or that it is likely to suffice in given circumstances to a specified degree. In which case an evaluation can turn into a likely fact.

So facts and evaluations are malleable in this way. This makes it hard to permanently label some assertion as a fact, and another as an evaluation. There is a negotiation in each piece of reasoning. And it goes further. I said, citing IMM Freiburg, that a complete air exchange 6 times an hour is a putative fact. Others might well call it an evaluation. Where there is a conflict, we can agree to differ. But any reasoning which depends on it will be, for me, primarily factual (based on facts) whereas for a colleague who does not accept the sufficiency of the air exchange rate as a fact, it will be hypothetical, based on what for her is an evaluation.

A third example. I experienced a case twenty years ago, while investigating what was known about the causes of single-event-effects (SEEs) in aircraft electronics, of a well-established "fact" concerning cosmic rays and SEEs, which I took to some particle-physicist colleagues to see what they thought of it. The response, "how could they possibly know that?", led me to look at the trail of reasoning. An assertion in a published peer-reviewed paper (PPRP) referenced another PPRP, which referenced another PPRP, which…. and eventually went back to a PPRP reporting one experiment, in which features supporting the assertion were highlighted. But, in that very paper, other prominent phenomena in the experiment that were at variance with that assertion were not discussed much at all. The claim had become "well established" because of a chain of repetition, not more. It was not a "fact" in my sense here, it was an oft-repeated, and to my mind skewed, evaluation of data from one experiment. I raised this (in astonishment at the time) to an experimental physicist colleague. "Oh, it happens all the time," he said. Repetition is not an intellectually legitimate way of turning evaluations into facts, but it appears to be a socially common one, even in science.

Keeping track of differential facts and evaluations, and tracking their progress through and influence in practical reasoning, is a non-trivial intellectual task. It is also important for intellectual progress in understanding such a disease as CoViD-19.

8 What Informaticians Could Contribute

The most important feature of infodemiology is that information itself is now critical to the safety of human beings. If you think CoViD-19 is like the 'flu, and you treat it nonchalantly, then you could die. There is the heart-breaking story of the young Texan, who attended a “Covid party”, and said to his ICU nurse just before he died, “I think I made a mistake…….” (Torres 2020). Informaticians are surely people with at least nominal expertise in handling and working information. If there is a need for dependable information and to counter misleading information about public safety, as is indicated by the varying ideas about Covid-19, then surely we could develop a speciality devoted to it.

First, information is not neutral. Facts are not necessarily isolated (some of them are: for example, 2+2=4) but often, even mostly, come with a context. They are “theory laden”, as the philosophers of science have it. That means, more mundanely than the philosophers meant, that if you don't believe that a drug has only local effects but affects all of your tightly-coupled interactively-complex body+mind in certain ill-understood ways, then somebody informing you to take dexamethasone for your cytokine storm will have to address its possible effects on the rest of your system in order to persuade you to do so. And, probably, explain persuasively why water with a “memory” of various interleukin antagonists/inhibitors is not going to help. Whereas to the rest of us “the RCT showed it works” suffices.

We informaticians usually do not bother to take the context into account. We just send our Excel tables around by email. That may no longer suffice. How do we communicate and manipulate facts-with-context? What are the differences with just communicating facts?

Second, we can work on ways to enhance networks of justified trust. Medical journals are familiar with this. There is peer review; there is critique; ways of enhancing what is perceived to be the trustworthiness of the information they proffer. But they are, almost for this reason, regarded as being part of the "medical establishment" – for some, trusted, but for others, part of the "untrusted elite". Those who are convinced by the "chem trails" interpretation of aircraft condensation trails do not trust NASA, whereas the rest of us know that NASA does fine engineering-scientific work. There are surely new ways of establishing trust, even amongst those with an aversion to elites. (Consider chem trails. You could invite chem-trails enthusiasts to an engineering tear-down of a high-performance jet, and then take them flying in the same jet in the right atmospheric conditions so they can see the condensation trail, ask them how they think it gets there, and answer the responses with another targeted partial tear-down upon landing. Providing of course you have deep pockets.)

Say, there could be a succession of (links to) FAQs presented on Facebook and Google instead of some of the advertisements. There could be various other "nudges". There are sociologists of science and technology who, notoriously amongst some scientists, do not consider the truth or falsity of the theories being discussed as at all relevant to the interactions between the scientists which they study. Such "Sociology of Scientific Knowledge" (SSK) scholars may well have insight into the kinds of negotiations which enhance and widen trust networks, and maybe these can be used by informaticians to introduce "elite" sources to a wider audience than those relative few who understand and believe "the science".

Third, informaticians tend to believe that "the facts speak for themselves", whereas we have seen that they may not. A specific evaluation of factual information does not always proceed inevitably from the information itself.

However, the information usually does constrain quite rigorously what valuations might be compatible with it and how far they reach. My colleague might opine that, having acknowledged the validity of Gödel's (and others') argument, I should be acknowledging the being, greater than which cannot be conceived, regularly at Sunday service. But it does not follow, to either of us, that I should be regularly indulging in confessions of sin, or in exorcisms.

Informaticians could analyse and enumerate evaluations consist with information-with-context conveyed. Not in every case, maybe, but where it might count.

Fourth, we could work at getting better at IT for medical and other social-safety purposes. I don't mean here what is referred to as medical IT, the information infrastructure of medical institutions, although that does need improvement. I mean information about matters concerning health for the population as a whole. The kind of stuff Professor Miller might consider as enhancing health-related education. For example, indicating clearly, everywhere, the material which is just plain right (hydroxycholoroquine doesn't help at all, at any stage, of CoViD-19) and indicating clearly, everywhere, the material which is just plain wrong (don't ingest bleach at any time for any reason, let alone CoViD-19 prophylaxis). With links to further information. It is not everything, but it would be a good start on Miller's education enhancement.

References

Agence France-Presse (2020) French professor faces disciplinary case over hydroxychloroquine claims, Report in The Guardian 2020-11-12. Available at https://www.theguardian.com/world/2020/nov/12/covid-professor-didier-raoult-hydroxychloroquine accessed 2020-12-22

Amendola, A et al (2021) Evidence of SARS-CoV-2 RNA in an Oropharyngeal Swab Specimen, Milan, Italy, Early December 2019, Emerging Infectious Diseases 27(2) February 2021 https://wwwnc.cdc.gov/eid/article/27/2/20-4632_article

Associated Press (2020) China delayed releasing coronavirus info, frustrating WHO, 2020-06-03, available at https://apnews.com/article/3c061794970661042b18d5aeaaed9fae , accessed 2020-12-07.

CDC (no date) U.S. Public Health Service Syphilis Study at Tuskegee, US Centers for Disease Control and Prevention, available at https://www.cdc.gov/tuskegee/index.html , accessed 2020-12-07

CDC (2020) US Centers for Disease Control and Prevention, Considerations for Wearing Masks: Help Slow the Spread of COVID-19, update of 2020-11-12, available at https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/cloth-face-cover-guidance.html

David, M (2015) The Correspondence Theory of Truth, Stanford Encyclopedia of Philosophy, https://plato.stanford.edu/entries/truth-correspondence/

Dembski, WA (1998) The Design Inference: Eliminating Chance Through Small Probabilities, Cambridge Studies in Probability, Induction and Decision Theory, Cambridge University Press.

Ektorp, E (2020) Death threats after a trial on chloroquine for COVID-19, The Lancet Infectious Diseases 20(6):661 on 2020-06-01 https://www.thelancet.com/journals/laninf/article/PIIS1473-3099(20)30383-2/fulltext

FID (2020-1) Forum for Information and Democracy, Working Group on Infodemics, information page, https://informationdemocracy.org/working-groups/concrete-solutions-against-the-infodemic/ accessed 2020-12-22.

FID (2020-2) Forum for Information and Democracy, Working Group on Infodemics, Policy Framework, November 2020 https://informationdemocracy.org/wp-content/uploads/2020/11/ForumID_Report-on-infodemics_101120.pdf accessed 2020-12-22

The Guardian Coronavirus Live Blog (2020) 2020-11-18, entry with timestamp 0317 UTC, https://www.theguardian.com/world/live/2020/nov/18/coronavirus-live-news-senator-chuck-grassley-tests-positive-airlines-offer-covid-testing accessed 2020-12-22

Gautret, P et al (2020) Hydroxychloroquine and azithromycin as a treatment of COVID-19: results of an open-label non-randomized clinical trial, International Journal of Antimicrobial Agents 56(1), July 2020, 105949, available at https://www.sciencedirect.com/science/article/abs/pii/S0924857920300996

Gettier, EL (1962) Is Justified True Belief Knowledge?, Analysis 20:121-3, 1963. Reprinted in (Griffiths 1967).

Glanzberg, M (2018) Truth, Section 1.3, Stanford Encyclopedia of Philosophy, available at https://plato.stanford.edu/entries/truth/#PraThe

Hamner et al (2020) High SARS-CoV-2 Attack Rate Following Exposure at a Choir Practice — Skagit County, Washington, March 2020, CDC MMWR 69(19):606-610 of 2020-05-15 Available at https://www.cdc.gov/mmwr/volumes/69/wr/mm6919e6.htm

Hartshorne, C (1962) The Logic of Perfection, Open Court Publishing.

Ladkin, PB, Neumann, PG (2020) Risks of Automated Theorem Provers, Risks Forum Digest 32.18. Available through https://catless.ncl.ac.uk/risks/

La Rosa, G et al (2021) SARS-CoV-2 has been circulating in northern Italy since December 2019: Evidence from environmental monitoring, Science of the Total Environment 750(1) January 1, 2021, 141711.

Legg, C (2020) Pragmatism, Stanford Encylopedia of Philosophy (revision of an original by C. Hookway, 2008), https://plato.stanford.edu/entries/pragmatism/

Li, Y et al (2020) Evidence for probable aerosol transmission of SARS-CoV-2 in a poorly ventilated restaurant, MedRXiv, 2020-04-22, available at https://wwwnc.cdc.gov/eid/article/26/7/20-0764_article

Lu, J et al (2020)Covid-19 Outbreak Associated with Air-Conditioning in Restaurant, Guangzhou, China, 2020, Emerging Infectious Diseases 26(7), July 2020 https://wwwnc.cdc.gov/eid/article/26/7/20-0764_article

Miller, B (2020) Science Denial and COVID Conspiracy Theories: Potential Neurological Mechanisms and Possible Responses, J. Am. Med. Ass. 2020;324(22):2255-2256, November 2, 2020 Available at https://jamanetwork.com/journals/jama/fullarticle/2772693

Miller SL et al (2020) Transmission of SARS−CoV−2 by inhalation of respiratory aerosol in the Skagit Valley Chorale superspreading event, Indoor Air 2020-09-26 DOI 10.1111/ina.12751 Available at https://onlinelibrary.wiley.com/doi/full/10.1111/ina.12751

Nozick, R (2001) Invariances, Belknap Press, Harvard University Press.

Oppy, G, ed. (2018) Ontological Arguments, Cambridge University Press, 2018.

Peeples, L (2020)What the Data Say About Wearing Face Masks, Nature 586:186-189, 2020-10-08 https://media.nature.com/original/magazine-assets/d41586-020-02801-8/d41586-020-02801-8.pdf , also on-line at https://www.nature.com/articles/d41586-020-02801-8

N. Peiffer-Smadja et al, Hydroxychloroquine and COVID-19: a tale of populism and obscurantism, The Lancet Infectious Diseases, 2020-11-13, available at https://www.thelancet.com/journals/laninf/article/PIIS1473-3099(20)30866-5/fulltext

Phillips Griffiths, A, ed., (1967) Knowledge and Belief, Oxford Readings in Philosophy, Oxford University Press.

Quine, WVO (1951) Two Dogmas of Empiricism, Philosophical Review 60(1):20-43. Reprinted as Chapter II of *from a logical point of view*, Harvard University Press 1953, revised 1961 and 1980.

Quine, WVO (1953) Reference and Modality, Chapter VIII of *from a logical point of view*, Harvard University Press, 1953, revised editions 1961 and 1980, available on-line at http://www.thatmarcusfamily.org/philosophy/Course_Websites/Readings/Quine%20-%20Reference%20and%20Modality.pdf

Quine, WVO, Ullian, JS (1978) The Web of Belief, 2nd Edition, Random House.

The RECOVERY Collaborative Group (2020-1) Dexamethasone in Hospitalised Patients with COVID-19 – Preliminary Report, N Engl J. Med., 2020-07-17. https://www.nejm.org/doi/full/10.1056/NEJMoa2021436

The RECOVERY Collaborative Group (2020-2) Effect of Hydroxychloroquine in Hospitalized Patients with Covid-19, N Engl J Med 2020; 383:2030-2040 DOI: 10.1056/NEJMoa2022926, available at https://www.nejm.org/doi/full/10.1056/NEJMoa2022926

Rorty, R (1979) Philosophy and the Mirror of Nature, Princeton University Press.

Rushby, J (2020) Mechanized Analysis of Anselm's Modal Ontological Argument, International Journal for the Philosophy of Religion, available on-line through http://www.csl.sri.com/users/rushby/abstracts/anselmp3 , accessed 2020-11-29.

Singh, S (no date) Who is Andrew Wiles? https://simonsingh.net/books/fermats-last-theorem/who-is-andrew-wiles/ accessed 2020-12-22.

Spahn, C, Richter, B, et al (2020) Risk Assessment of a Coronavirus Infection in the Field of Music, update of 2020-07-17, Freiburger Institute für Musikermedizin an der Hochschul für Musik Freiburg, https://www.mh-freiburg.de/fileadmin/Downloads/Allgemeines/RisikoabschaetzungCoronaMusikSpahnRichter17.7.2020Englisch.pdf

Torres, E (2020) 30-year-old dies after attending 'COVID party' thinking virus was a 'hoax', BC News 2020-07-11. Available at https://abcnews.go.com/US/30-year-man-dies-attending-covid-party-thinking/story?id=71731414 accessed 2020-12-22.

van Doremalen, N et al (2020) Aerosol and Surface Stability of SARS-CoV-2 as Compared with SARS-CoV-1, New England J. Med. 2020;382:1564-1567, https://www.nejm.org/doi/full/10.1056/nejmc2004973 published 2020-04-16.

Ward, M, Shapir, A, Ladkin, PB (2020) Re: Darwin's Tautology? Risks Forum Digest 32.15, 32.16, 32.17 Available through https://catless.ncl.ac.uk/risks/

WHO (2020) 1st WHO Infodemiology Conference, https://www.who.int/teams/risk-communication/infodemic-management/1st-who-infodemiology-conference , World Health Organisation, accessed 2020-12-22

Wikipedia (no date) Brian Josephson https://en.wikipedia.org/wiki/Brian_Josephson , accessed 2020-12-07.

Wikipedia (no date) Level of Support for Evolution (United States Entry) https://en.wikipedia.org/wiki/Level_of_support_for_evolution#United_States

Wittengstein, L (1921) Tractatus Logico-Philosophicus, original 1921 with translation by D.F. Pears and B.F. McGuinness, Routledge Kegan Paul, 1961.