The mechanics and determinants of anti-science attitudes: a literature review

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Abstract

This literature review forms part of a larger program, that of the redefinition of the Laboratory for Interdisciplinary Evaluation of Public Policy's (LIEPP) research axes. It aims to explore, summarise, and discuss the existing literature which gives insights into the nature and the workings of anti-science attitudes. To this effect, this review draws on literature from various academic fields, such as history, philosophy, political science, psychology, and sociology, and touches upon several topics that are relevant to the study of anti-science attitudes, like the environment, public health, and scientific governance. It eventually provides an overview of anti-science attitudes, of their mechanics and their determinants, in order to foster reflexion over the stakes of the public's perception of science and over ways to improve it.

Keywords: anti-science, pseudoscience, science denial, literature review.

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Introduction

In the context of the COVID-19 pandemic, the topic of attitudes towards science has gained much salience. Since December of 2019, when the first COVID-19 patients were admitted into hospital, many controversies relating to scientific discourse have come under public scrutiny. Lay publics, be they politicians or members of the general public, have taken some scientific matters into their hands, debating scientific evidence and discourses in the public sphere. Scientists have also brought such issues into the public arena as they made appearances in lay medias in order to offer their views on salient scientific debates, such as the effectiveness of the use of masks to prevent the spread of the disease, the possibility that humans develop (herd) immunity to SARS-CoV-2, or even regarding the prevalence of infections within populations. As of then, scientific questions that had hitherto remained within scientific communities were regularly seized by members of the public. Thereafter, it became commonplace that public personalities promote discourses challenging some scientific consensus, accuse scientists and decision-makers of hiding the truth of the virus to the public, going so far as to accuse some actors of voluntarily creating and spreading the virus. The COVID-19 pandemic is an unprecedented crisis that, in a relatively short period of time, has led to a strong politicisation of scientific debates, which are usually distant from the public eye as they remain within the confines of scientific communities. Lay persons and scientists alike sometimes hastily took positions in scientific debates contributing to dissonant scientific discourses and the polarisation of public opinion. Furthermore, the crisis also invigorated the circulation of fake news, both new and old, and conspiracy theories.

Though the topic of anti-science attitudes may seem more salient than ever, it is certainly not new. It was in Ancient Greece that the first hypotheses concerning the spherical shape of the earth were formulated, displacing earlier beliefs that it is flat. Yet, after centuries of scientific consensus, this claim is still put up for debate by the members of modern flat Earth societies. Likewise, despite nearly two centuries of scientific consensus over the theories of Darwinian evolutionary biology, various groups still oppose them in favour of creationist theories of life. Creationist objections have caused various debates over the teaching of evolution at school, particularly in the United States. The weaponisation of science has also sparked public debate over the utility and morality of science, causing opposition over the use of some technologies. Anti-science attitudes that have been more salient in the past few decades concern vaccination and anthropogenic climate change, with much reluctancy and resistance being expressed towards scientific discourses by various actors at distinct levels.

In modern societies in which the merits of science are often highlighted, where decisions are meant to be informed and justified by science, there are important stakes in understanding attitudes towards science. Growing conscientisation in regard to these stakes is reflected in academic production and public debates that have been taking place over the past few decades. For example, since 1992, there is an academic journal specifically dedicated to the public understanding of science. Over the past decade, there has been a noticeable rise in academic interest regarding anti-science attitudes, as illustrated by Figure 1, and particularly around issues linked to vaccination resistance and anthropogenic climate change denial.

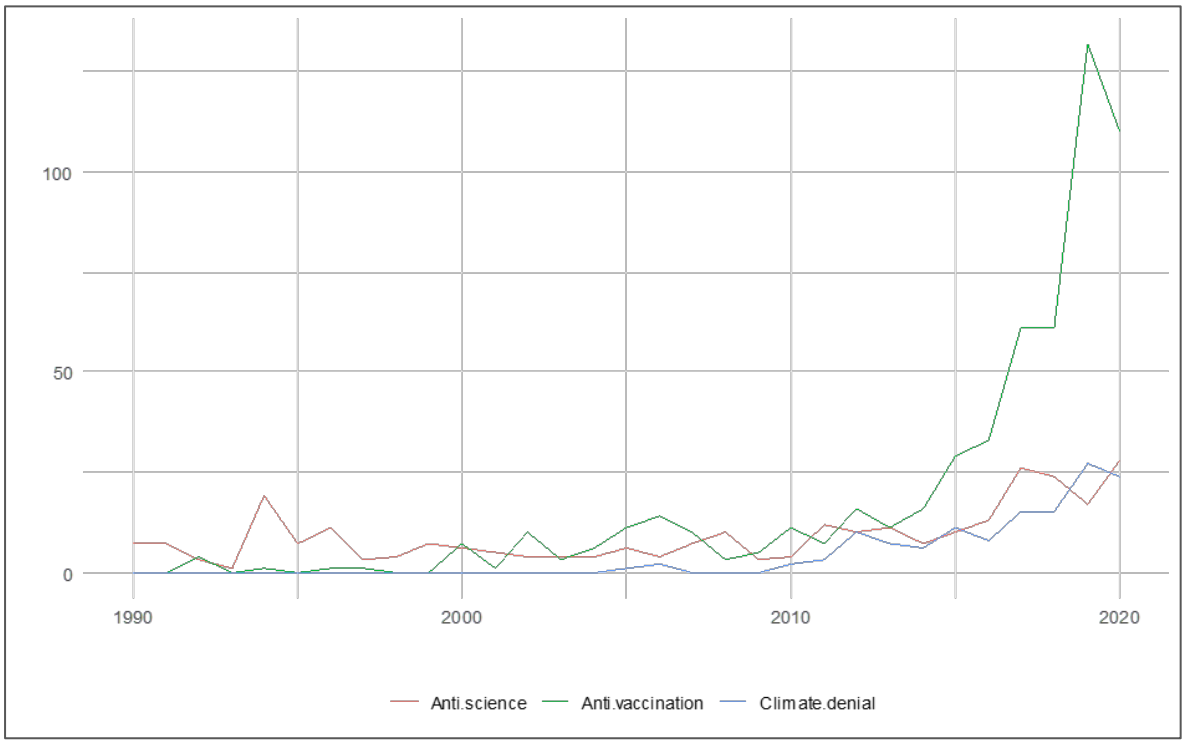

Figure 1. Anti-science, anti-vaccination, and climate denial academic publications (1990-2020)[2]

Anti-science attitudes are rarely apprehended as an object in the literature, and unsurprisingly so, since they encompass a very large and highly heterogenous range of attitudes, which may or may not be compatible with each other and which may result from various beliefs or mechanisms. As such, an enquiry using the keywords "anti-science" on an academic search engine does not yield much results which may help bring insights into the mechanics and determinants of anti-science attitudes. Rather, it brings into light a plethora of petty academic quarrels over the scientific virtues of one field or another. Another option would then be to lead a systematic search with keywords specific to some issues such as climate change, anti-vaccination, or creationism for example. However, this method – even when topics are crossed with keywords such as "perceptions, "public opinion", or "attitudes", amongst others – yield either unreasonably large amounts of results, most of which are off-topic, or very few results. Moreover, a problem with this method would be the systematic exclusion of some types of anti-science attitudes, either because they are little known or because different referral terms are employed. On the whole, a series of search methods were tested with the intention of systemising the present literature review, they however appeared to be rather limited in the apprehension and comprehension of anti-science attitudes. The literature that is here mustered and discussed is in part drawn from preliminary searches using aforementioned keywords, from the bibliographies obtained with said searches, as well as with searches in specific interdisciplinary topic-based journals such as Public Understanding of Science, Science

[2] Results from searches performed on the Dimensions database on October 14th, 2020 ["anti-science" OR "antiscience], ["anti-vaccination" OR "antivaccination" OR "anti-vax" OR "antivax"], ["climate denial" OR "climate skepticism" OR "climate scepticism"] in title or abstract.

Communication or Vaccine. Since anti-science attitudes are not an established object or topic in the literature, these mixed literature searches seemed more appropriate in an endeavour to fathom the breadth of academic contributions that enlighten some of the many elements involved in the development and adoption of anti-science attitudes.

After reading over a hundred academic articles and books hence found, the challenge was that of harmonisation. How to offer a comprehensive summary of the mechanisms that have been identified in the development of various and often contradictory attitudes under the umbrella of anti-science attitudes? Reviewing the literature per topic, that is per type of anti-science attitude, would not provide for much progress in furthering general understandings of anti-science attitudes. Moreover, there exist several systematic literature reviews on some of the aforementioned topics, such as climate science denial (Björnberg et al. 2017), vaccine hesitancy (Larson et al. 2014), the psychology of conspiracy beliefs (Goreis and Voracek 2019), and the tobacco industry's lobbying strategies (Smith, Savell, and Gilmore 2011; Savell, Gilmore, and Fooks 2014). As such, this paper tackles the question of the conceptualisation of anti-science attitudes from a theoretical and historical perspective (1), before reviewing the different psychological mechanisms and individual motivations that incite people to believe in and support anti-science claims (2). It thereafter delves into the part that elites play in the formation and circulation of anti-science attitudes (3). Finally, a more normative section looks into some remedies that have been highlighted in the literature to better people's relationship to science (4).

I. Thinking anti-science attitudes

Anti-science attitudes are not a monolithic and linear phenomenon. They indeed encompass large amounts of attitudes, going from scepticism regarding certain technologies to the outright rejection of consensual scientific discourse. They may simply be beliefs held by some individuals, or they may also include the dissemination of pseudoscientific material and/or involve obstruction of the scientific process, as well as intentional disinformation. Considering the disparate natures of anti-science attitudes, the manifold domains they touch, and the various actors that are implicated, it is crucial to stop for a moment and take some time to think the object(s) at hand before delving into their determinants and their effects.

1.1. What are anti-science attitudes?

Writing about science denial in general terms, Diethlem and McKee (2009) identify five characteristics of anti-science attitudes. First, they include conspiracy theories, that is beliefs that powerful actors may tweak or invent scientific findings in order to advance their own interests. Second, science denialists often rely on fake experts in order to, supposedly, and in a seemingly legitimate manner, debunk scientific material. They may also rely on corrupt experts (Karlsson 2012: 4-6), hence fake expertise. Third, cherry-picking information and evidence is typical of anti-science: where science is based on replicable and representative results, detractors will use sensational and anecdotal information to support their claims. The most telling example of such practices is probably that of anti-vaccination activists claiming

that the administration of vaccines causes the development of autism in young children. The fourth characteristic is the misrepresentation of what research can achieve, that is attributing unreasonable objectives to science. For instance, the unforeseen side of biological medicine has eroded public opinion over the trustworthiness of scientists. That is part due to a misrepresentation of what research can achieve for, in this case, scientists cannot guarantee that there exist no chances for dangerous side effects, they can only affirm that these chances are low (Tournay and Pariente 2018). Finally, much of anti-science relies on fallacious reasoning, such as claiming that anthropogenic climate change is a scam because the weather is cold.

Anti-science attitudes range from scepticism towards scientific discourses to the sheer rejection of a scientific consensus and the fabrication of supposedly scientific evidence to undermine scientific discourse. These should not be understood as a monolithic or binary phenomenon, one is not "anti-science". Rather, "varying levels of trust in science can be observed within individuals, individuals can trust science on one issue more than another, and trust in science depends on the type of science in question" (Pechar et al. 2018: 293-4). Likewise, similar anti-science attitudes may be the result of different mechanisms or trajectories. For example, Ward (2017) argues that different trajectories led to A(H1N1) vaccine criticism: on the one hand, conditional critics condemn this particular vaccine, putting forward arguments linked to the environment or to the effects of some adjuvants, without questioning vaccination as a practice; on the other hand, the claims of unconditional critics dispute vaccination as a whole and are often rooted in beliefs in the efficiency, and often superiority, of alternative practices that are considered to be pseudoscientific. Similar anti-science attitudes, such as the rejection of a particular vaccine, may stem from distinct logics and beliefs, making it essential to have as nuanced and layered an analysis as possible when trying to understand their determinants.

1.2. How do denialists deal with science?

Different types of reasoning may be behind anti-science attitudes. In the context of climate science denial, Ferkany (2015) argues that anti-science attitudes may be placed on a spectrum ranging from "naïve" to "motivated" denial of scientific evidence. The naïve end of the spectrum is largely marked by ignorance, corresponding beliefs are not the result of an informed decision but rather of a hasty positioning that is often based on cognitive shortcuts. This type of climate science denial may also be rooted in the fear of the full implications that acknowledging a problem may have on one's life (Norgaard 2011), it may be easier to ignore the problem than to address it. At the other end of the spectrum, Ferkany explains that "the motivated denier is driven by the belief that the steps we must take to deal with the problem are incompatible with deeply held ethical or political beliefs" (2015: 710). In other words, science functions as a belief system and may clash with other belief systems, in which case one may decide that the latter primes over the former, hence becoming a motivated denier. A striking example is that of well-informed and highly-educated persons who prefer the theory of Intelligent Design – according to which the world is so complex that it was necessarily created by a superior intelligent force – over that of biological evolution; their denial is

motivated by a greater explanatory value given to one over another, in full awareness of the existence of both.

Science may advance “uncomfortable knowledge” (Rayner 2012) because it conflicts with worldviews we hold, or it disserves private economic or political interests, amongst other reasons. According to Rayner, who also writes about climate science denial, there are four ways in which one may deal with uncomfortable knowledge. One such strategy is denial, which consists in the outright refutation of scientific evidence. A second strategy is that of dismissal: one may admit that there exists a problem but consider it to be too benign to require any action. Diversion is when one acknowledges the problem and assures that one is working on resolving it, all the while not properly addressing it. Finally, displacement consists in affirming that the problem is being solved, though not necessarily efficiently.

The identified strategies are relevant to think the dismissal of science that points out problems that may be related to some behaviours and practices we have, thus generating uncomfortable knowledge. Examples include evidencing the risks presented by anthropogenic climate change or the harmfulness of certain chemicals for public health. This analysis of science denial may also be extended to dismissive attitudes towards scholarship that points to classist, heterosexist, racist, or neo-colonialist patterns and structures in societies, under the pretext that they do not exist (denial), that they are “minor problems” (dismissal), or that some solutions, whether already deployed or not, are dealing with or will deal with the problem (diversion and displacement). It is indeed an uncomfortable task to think relations of domination, especially when one is in a position of dominance. In the face of uncomfortable knowledge, which risks perturbing people’s habits and putting into question the entirety of their behaviour and some of their beliefs, they may be quick to disregard scientific evidence however solid it may be – and this includes scientists themselves.

1.3. Science, anti-science, and politics

Science is often imagined as seeking objective truths in order to advance our understanding of the world and our mastery of technologies. It is however not void of political intent. Historians, philosophers and sociologists of the natural sciences have evidenced how it has been used in the past to create and ferment hierarchised social orders. Under the cover of being science, pseudoscience or anti-science has been instrumental to manipulate opinions and to uphold the social control of dominant groups over populations.

◊ *Race*. Intellectuals were the first persons to speak about human races, comparing them to animal races, and to hierarchise them. This line of thought was commonly used by prominent thinkers to justify the European colonisation of many territories under the pretext that it was the West’s mission to “civilise” other peoples. In the United States, which have a long history of racial segregation with pervasive consequences, Audrey and Brian Smedley (2011) have argued that science’s role in dividing humankind into hierarchised “races”, hence legitimising racist behaviours and policies, may be at the origin of a lower trust in science amongst African-American and other non-white populations. The infamous Tuskegee experiment, which caused a bioethical scandal, is one example of the practices that may have caused the erosion

of trust in, if not the outright loathing of, scientists and scientific institutions. In a clinical trial for syphilis treatment, which stretched from 1932 to 1972, scientists in Alabama recruited six hundred African American sharecroppers, some of whom had already contracted syphilis. The involved scientists sought to study the natural history of syphilis which they believed to be a disease of "black men". Doctors had only told patients that they were being treated for "bad blood" and refused to treat them with penicillin, despite it having become the generic treatment for the infection by 1947, leaving them to suffer and eventually die. The Tuskegee experiment is not the only one of its sort (see Washington 2008), but it stands as a reminder that scientific racism is not solely something of the past, and it shows the ethical dangers of scientific uncertainty and approximation (Reverby 2009).

◊ *Class*. It is another element structuring social hierarchies that may affect attitudes towards science. It is illustrated by historian Nadja Durbach's work on the late 1800s anti-vaccination movement in Great Britain. The movement was one located amongst working-class people. The motivations behind it were not so much linked to a potential hazardousness of vaccines as such, but rather to their compulsory nature and to the conditions in which they were imposed to workers' children (Durbach 2002). Working-class parents who did not have the means to consult a private doctor were indeed summoned to bring their children to public vaccination posts where needles were shared between children. The stakes of anti-vaccination grew even more as the conservative response to workers' demands for a "conscientious objection" clause reflected the country's elite disdain towards workers. It then became a matter of redefining consciousness and citizenship which understandings were restricted both in classed and gendered terms.

◊ *Gender, sex, and sexuality*. Historically, science has also been used to justify and enforce hierarchical relations between men and women by pathologising some behaviours. For example, for over a century, medical definitions of hysteria have been used for the social control of women. The figure of the hysteric woman, which was the result of the interaction of social prejudice and medical diagnosis, was opposed to that of the perfect woman, she who is a good wife and mother (Edelman 2003). This social order hierarchising sexes and defining genders, also operated with the control of sexualities. Women who were considered to have too high a sex drive were nymphomaniacs, those who had sex with other women were either "congenitally inverted" or "sapphics" – only the former was "sick" for she took up the role of a man and tricked the latter into sinful practices. Inhumane treatments such as lobotomies, electroshock therapies or conversion therapies were condoned by science to treat these "anomalies". Medical science has a long history of enabling the stigmatisation and enforcing the repression of "deviant" behaviours (see Becker 1963). Today, medical biology is largely criticised by intersex activists who contest the supposedly pre-discursive nature of sex, that is contesting the supposed natural and organic origin of sex as a category and understanding it as a discursive invention.

What these cases reveal is not necessarily a rejection of science for itself, but a rejection of the authority which carries scientific discourse and transforms it into public policy. When this authority is known or perceived to disregard, marginalise, and stereotype some populations, then it may be rebuffed by these same populations. Whether that be in consideration of the

science itself or not. It is hardly startling that those peoples who have historically been oppressed or discriminated by scientists or decision-makers backed by science would be sceptical of science. A recent example is that of French Guyanese COVID-19 patients who, amidst the hydroxychloroquine polemic, refused to participate in a clinical trial for a plasma therapy treatment – that is, a treatment using blood plasma from patients who have already developed antibodies – which would have been led by metropolitan doctors. They indeed feared the former sought to use them as "lab rats" and to keep the "good medicine" (hydroxychloroquine) for trials in the metropole[3]. The context in which one is embedded may be an important predictor of attitudes towards science (Kahan, 2018), considering what science may stand for in this particular context.

An approach lacking in the literature which may enlighten the more or less pervasive effects of the historical use of science to maintain unequal social orders, is that of people's ordinary relationship to science. How are they received by nurses and doctors in hospitals? The recent death of Joyce Echaquan, an indigenous woman who faced racist comments and behaviours when admitted to a hospital in Canada, is one of too many examples that prompts reflexion and illustrates the need for action in this regard. How are they treated by practitioners? Do they feel like they are looked down upon because of their level of education? Do they feel like scientists behave in a condescending manner? To what extent do past abuses of science influence anti-science attitudes today? While Gordon Gauchat (2008) provides interesting insights by testing the effects of social embeddedness – measured according to survey respondents' employment status, marital status, political participation, and the frequency at which they attend social gatherings – on trust in science; perhaps more qualitative research looking into how inequality structures may affect people's perceptions of science would provide for additional discernment.

II. Explaining anti-science attitudes: individual perceptions of science

Science is a set of vastly complex and extremely specialised enterprises. As such, the efficiency of its communication relies in large part on the perceived integrity of scientists as advisors. It is to be noted that the trust placed in one institution, or another does not necessarily rely on its *actual* transparency and efficiency, but rather on *perceptions* of said transparency and efficiency (Tournay 2014). Considering the complexity of scientific evidence and reasoning that constitute the basis for scientific discourses, laypersons may use cognitive shortcuts or refer themselves to opinion leaders to assess their credibility. These may in turn influence perceptions of and trust in scientific institutions. It is then not science per se that is questioned, but rather those who produce and diffuse it and their *perceived* propensity to respond to personal interests over seeking objectivity, that is the *perceived* integrity of scientists and scientific institutions. As such, this section seeks to offer a summary of the individual-level mechanisms that are involved in the formation of defiant attitudes towards scientific institutions and communities. To this effect, it first reviews the psychological

[3] Libération (2020a), "Bons baisers de Guyane (avec un masque)", available: https://www.liberation.fr/france/2020/08/06/bons-baisers-de-guyane-avec-un-masque_1796125 [14.08.2020].

mechanisms that are involved in the formation of anti-science attitudes and subsequently looks into the different motivations that have been identified in the literature to explain such attitudes.

2.1. The cognitive mechanisms behind anti-science attitudes

To deal with the extremely intricate nature of scientific enterprises, people should rely on cognitive shortcuts to formulate opinions regarding different scientific issues. Preconceived ideas, membership to a particular social group, or scientific cognition are a few factors that may influence individuals' perceptions of scientific discourses. This section looks into the different cognitive biases and defence mechanisms that may shape people's perceptions of science, be they positive or negative.

2.1.1. Socio-cultural cognitive biases

Social psychology offers valuable tools to understand how and why one may durably adopt anti-science attitudes. Some socio-cultural factors indeed feed cognitive biases that influence information reception and opinion formation, and therefore the ways in which one perceives the world.

Social identity theory (see Tajfel 1982) brings some interesting insights into the understanding of anti-science attitudes, for it explains the convergence of attitudes amongst individuals who form part of a same group, as well as their long-lasting nature. Social identity is derived from one's own knowledge of one's membership to a social group, that is self-categorisation, and concomitantly to the comparison of the group one belongs to with other existent groups, that is social comparison (Hogg and Abrams 1988). Self-categorisation results in "an accentuation of the perceived similarities between the self and the other-in-group members, and an accentuation of the perceived differences between the self and out-group members" (Stets and Burke 2000: 225). Social comparison is based on the status that each group holds in an already structured society, which may be related to groups' power, prestige, material characteristics, etc. Social identity theory was originally formulated to explain intergroup relations, by doing so it highlights some in-group mechanisms that contribute to the transformation and reinforcement of certain attitudes which are formed according to constant in-group-out-group comparisons. As individuals derive their self-concept from their attachment to one group, they may transform their attitudes in order to further their self-identification to said group. In the context of anti-science attitudes, this may result in a biased perception of science and scientists according to social identity.

Social identity may be linked to holding certain values and/or sharing a particular perception of out-groups – for example, scientists may be perceived as out-groups by lay persons. It has been argued that the values that individuals hold may influence their reception of certain scientific discourses in consideration of their implications – that is, their risk perception – and may hence affect the trust they exhibit towards one institution or the other (see Douglas and Wildavsky 1982, Wildavsky and Dake 1990, Rayner, 1992). On the one hand, those who have more hierarchical and individualistic values tend to be more sceptical of discourses claiming

the dangers of anthropogenic climate change, of certain chemicals, or of nuclear waste disposal, to only name a few examples. Agreement with such discourses would indeed involve support in the restricting of commerce and industry, which are widely considered to be motors of this phenomenon. On the other hand, those who tend to have more communitarian values also tend to resent those same sectors, commerce and industry, and are therefore more likely to adhere by discourses suggesting that they be restricted. In-group values, based on the evaluation of out-groups, may influence the way in which individuals perceive scientific endeavours and the risks they entail.

Elaborating on this theory of risk perception, Kahan et al. (2011) suggest that the likelihood that an individual considers a person as an expert or some piece of scientific information as true is related to their cultural cognition of scientific consensus. They argue that, given that laypersons roughly follow a Bayesian model of inference in their reasoning (cf. Raiffa 1968) – i.e. a probabilistic form of reasoning in an uncertain environment – the probative weight they give to new evidence is endogenous to priorly held beliefs, or "cultural values" (Kahan et al. 2011: 167). As such, if scientific evidence contradicts these beliefs, a layperson is likely to overestimate the number of experts who disagree with this evidence and to need a substantially greater amount of evidence to change their mind. These beliefs and values may be linked to one's political orientation and/or religious confession, for example, and hence to their self-categorisation.

2.1.2. Metacognitive biases

The Dunning-Kruger effect underlines a metacognitive paradox – that is, one's cognition of their own cognition – whereby ignorance, rather than knowledge, is associated to self-confidence (see Kruger and Dunning 1999). In other words, according to this theory, individuals who are not competent in a certain domain tend to over-evaluate their own capacities. This overconfidence bias roughly corresponds to a "it can't be that hard" reasoning on the part of profanes in any particular domain. In the case of science, a partial training may result in a non-competent person being overconfident regarding their ability to understand scientific methods and evidence. This person may hence put forward some pseudoscientific arguments, portraying anecdotal evidence as tangible evidence and asserting that the ensuing conclusions are facts.

Anti-science attitudes stemming from overconfidence may lead to public health hazards. To holistically apprehend a complex scientific question, a solid methodological and disciplinary training is most often necessary. Merely dabbling into such questions runs the risk of only acquiring a partial understanding of the objects and stakes at hand. It has been argued that the Dunning-Kruger effect may in part explain support for homeopathic practices and, anti-vaccinationist attitudes (Arthur 2017), or Lyme disease advocacy (see Auwaerter et al. 2011). Medical laypersons, by dint of reading about vaccination, may think that they have somewhat become specialists of the question, or at least that their knowledge is sufficient to oppose themselves to a scientific consensus, or to put forward the lack of scientific medical knowledge in one area. However, considering their lack of medical scientific training – to distinguish from a practitioner's medical training – they will most probably turn to vulgarised

information that has been shared by anti-vaccination activists themselves which, in turn, is often based on anecdotal evidence and therefore constitutes pseudoscientific discourse. For instance, naturopaths are often accused of quackery by the medical body as they usually have little knowledge regarding conventional medicine and yet they may confidently dissuade cancer patients from having tumour removal surgery, for example. Overconfidence may lead laypersons to firmly believe anti-science – in that they contravene scientific consensus – claims.

2.1.3. Defence mechanisms

Psychologists and philosophers have pointed to several defence mechanisms that allow individuals to hold anti-science beliefs by making them invulnerable (Boudry and Braeckman 2010) when confronted to evidence refuting them.

Epistemic defence mechanisms are inherent to some belief systems which systematically dismiss and deflect new arguments and evidence that is presented. Boudry and Braeckman (2010) use the example of conspiracy theories to illustrate this mechanism. Conspiracy theories oppose official accounts of particular events, they construct alternative explanations that are based on dissonances in official discourses and other "errant data" (Keeley 1999: 118). The logic on which all such theories are based is that a supposedly malevolent elite is pulling the strings and attempting to hide its wrong doings by spreading fabricated stories regarding the events in question. As such, any new evidence that is presented to refute a conspiracy theory will be systematically deflected as it may just be accused of being an artifact sculpted by this same elite to offer support to this same fabricated story. This pattern of epistemic defence mechanisms is inherent to all conspiracy theories, in which any contradiction is seen as the action of conspirators and therefore further ferments the conspiracy theory.

While epistemic defence mechanisms are a "structural feature" of some belief systems, an immunising strategy is "an argument brought forward in support of a belief system, though independent from that belief system, which makes it more or less invulnerable to rational argumentation and/or empirical evidence" (Boudry and Braeckman 2010: 145). A good example of an immunising strategy is that of the Omphalos hypothesis, which contributes to supporting creationist claims, as it argues that the geological evidence that is used by scientists to explain the evolution of life on Earth is but a device created by God to test our faith. Immunising strategies ad hoc arguments that may use to skirt scientific evidence and discourse in order to substantiate a pseudoscientific theory.

Similarly, it has been argued that accuracy is only one psychological incentive amongst others, which may be trumped by the desire to defend untestable religious or political beliefs for example. Bortolotti (2015) has argued that delusion can be motivated, especially when it comes to ontological questions for which our understanding of truth can only be approximate at best. Though delusion entails an epistemic cost – for it furthers one from the truth – it may also generate substantial epistemic benefits by presenting an alternative truth from which motivation stems. In other words, it may be easier for one to draw a sense of self and purpose from an apparently all-encompassing theory of life such as creationism rather than from

evolutionary biology for example, therefore generating "motivated disbelief". To this effect, one may include some aspects of "unfalsifiability" to one's belief system, whereby the issue is considered to be a matter of moral rather than one of facts (Frisen, Campbell, and Kay 2015). One's claim thus cannot be falsified for morality is untestable, and when the associated beliefs clash with the postulates of science then they also challenge science as an epistemic authority.

The aforementioned defence mechanisms evidence how individual apparatuses may be put into place and influence the frames through which individuals filter, receive, and decide or not to accept new information (see Zaller 1992). They therefore may explain why some individuals have trouble believing in seemingly abstract scientific postulates and consequently fall back on alternative belief systems.

2.2. Manifestations of and motivations for anti-science attitudes

Perceptions of science are essential to understand support for certain scientific claims. Taking the example of the anthropogenic climate change controversy in the United States, van der Linden et al. (2015) identify perceived scientific consensus as a "gateway belief". In other words, if one believes that there is a scientific consensus on the question, then one is more likely to believe that anthropogenic climate change is indeed happening. Building on this work, Gauchat et al. (2017) argue that the credibility of scientists may be rooted in perceptions related to three matters: their understanding of climate change, the integrity of their policy advice, and consensus amongst scientists. They find that the former two aspects are actually more important determinants of scientists' credibility in the public sphere. How we decide whether a scientific claim is consensual or not, whether scientists have integrity or not, is not necessarily a function of *actual* consensus and transparency. Rather, our *perceptions* may be influenced by some values or beliefs we hold, some worldviews, or our understanding of certain scientific issues. This section hence reviews the different individual motivations for anti-science attitudes that have been highlighted in the literature.

2.2.1. Religious beliefs

Religiosity is often discussed as a potential determinant of anti-science in the existing literature (see Ellison and Musick 1995, Gauchat 2008, Selepak 2018, Rutjens et al. 2020). In the context of the United States, historian Richard Hofstadter has linked the rise of anti-intellectualist sentiments to evangelical influences, for evangelism preaches a direct relationship with God. It is then not so much science per se that is contested, but its status as a higher authority (Hofstadter 1963). Along similar lines, James Hunter argues that the US has seen a realignment of moral and religious values engendering a culture war between, on the one side, the religious orthodox and, on the other side, the secular progressists. Be it in regard to women's rights, LGBT rights, or funding of the arts, the controversies of the late XXth century in the US represented a conflict over a moral authority rather than an epistemological authority (Hunter 1990). And indeed, the question of morality may be important in understanding science reception, since taking moral offense in scientific

discourse is positively associated to opposition to this same discourse (Colombo, Bucher, and Inbar 2016).

Besides questions of morality, a positive relationship between religiosity and anti-science attitudes may be the result of the conflicting nature of postulates made by scientific authorities and religious ones, since both science and religion function as ultimate explanatory paradigms (Rutjens et al. 2020). It would indeed be incoherent for one to believe in both creationism and Darwinian evolutionary biology for they offer fundamentally conflicting explanations of the origins of life and humankind. Depending on one's conception of religion and one's religious beliefs, religion may be considered as an epistemic authority which trumps science.

2.2.2. Political preferences

As politicians often summon science to justify and legitimise their policymaking, trust in scientists may then be correlated to trust in the politicians who mobilise them to support one policy or another. Hence, "when there is a societal debate, public trust [in science] often becomes a function more of political ideology than of scientific fact" (Resnick, Sawyer, and Huddleston 2015: 21). There is a growing polarisation over scientific discourses, especially over politically salient issues such as climate change, along partisan lines in the United States (Dunlap and McCright 2008, Dunlap et al. 2016). In this context, it has been suggested that those people who identify as conservative or Republican tend to be more distrustful of science than those who identify as liberal or Democrat (Mooney 2005), because there exist fundamental psychological differences between the two groups that make the former usually more resistant to the changes that may be brought about by science (Mooney 2012).

While political conservatives may have historically shown more opposition to new science and technologies, some nuance should be brought to such an analysis. In a relatively recent experiment, Nisbet, Cooper, and Garrett (2015) refute this "intrinsic thesis" that seeks to explain conservatives' negative attitudes towards science by arguing that they are the result of inherent psychological deficiencies. Rather, they argue for a "contextual thesis", as they find that liberals like conservatives tend to oppose those scientific discourses that they find politically dissonant. This claim is further substantiated by Washburn and Skitka's (2017) experimental study, which suggests that the acceptance of science is based more on attitude-consistency than on political ideology. These findings echo McCright et al.'s (2013) claim that, because they hold different values and have distinct priorities, liberals are more likely to trust science showing the negative impact of human activity on the environment, while conservatives are more inclined to support science that seeks to promote economic production. Campbell and Kay (2014) have called this type of mechanism motivated reasoning, that is "motivated disbelief" which corresponds to "an aversion to the solutions associated with the problem" (p.809). Moreover, trust in science may be influenced by the perceived political bias of scientific institutions. For example, Selepak (2018) suggests a perceived institutional liberal bias, which may stem from universities' communication on social media, is a more important determinant of anti-science attitudes amongst political and Christian conservatives than an actual liberal bias within faculty.

2.2.3. Anti-elitism: populist and conspirationist worldviews

Some sceptical cognitive orientations may lead individuals to systematically be wary of (scientific) elites, and hence of the scientific institution as a whole. In a context where political commentators and scientists have identified a global rise of populism in recent years, and even a transition to post-truth populism (Speed and Mannion 2017), one may wonder whether populist discourses, typically denouncing an out-of-touch and corrupt elite, influence general perceptions of science. Populist characteristics indeed include systematically defiant attitudes towards authorities, and this may well include science as an epistemic authority. In an attempt to conceptualise science-related populism, Mede and Schäfer (2020) have defined it as "a set of ideas suggesting an antagonism between an (allegedly) virtuous ordinary people and an (allegedly) unvirtuous academic elite – an antagonism that is due to the elite illegitimately claiming and the people legitimately demanding science-related decision-making sovereignty and truth-speaking sovereignty" (p.12). Worldviews that tend to be systematically sceptical of elites, and which may be more or less founded, may well fuel general feelings of distrust towards scientists. For example, Kennedy (2019) finds a positive relationship in between vaccine hesitancy and support for populist parties.

In the context of anti-science attitudes, the concept of "conspiracy mentality" has received much attention. According to Landrum and Olshansky (2019), it corresponds to "a political worldview consisting of general feelings of distrust or paranoia towards government services and institutions, feelings of political powerlessness and cynicism, and a general defiance of authority" (p.194). As such, conspirational thinking may also be a systematic cognitive orientation that leads individuals to be distrustful of authorities, including scientific authorities. It has been suggested that exposure to anti-vaccine conspiracy theories has a negative effect in vaccination intentions (Jolley and Douglas 2014). In the context of the COVID-19 pandemic, Miller (2020) has shown that conspiracy theories seeking to explain the origin of the virus, despite them sometimes being contradictory, form a monological belief system. That is because belief in conspiracy theories is not based on the evidence supporting them, or lack of, but rather on a worldview according to which elites and authorities are not to be trusted. Moreover, Miller argues that people's tendency to believe in conspiracy theories is accentuated in climates of uncertainty where (scientific) elite discourse may appear to be, and may well be, more hazardous.

The existing literature provides interesting insights into some of the psychological mechanisms that define public perceptions of both science and scientific elites. Once again, it is worth noting that most of the literature at hand draws data from the United States. Besides the fact that much academic production comes from the country, it may be assumed that such pronounced interest stems from the fact that it is often an important protagonist in conspiracy theories. The COVID-19 pandemic presents a rather interesting opportunity for a natural experiment to expand studies looking into conspirational thinking beyond national borders: have conspiracy theories emerged and gained supporters more in some countries or regions that in others? Why is that so? Do certain power structures encourage conspirational thinking? Is there indeed a cultural bias in risk perception?

2.2.4. Scientific knowledge

Some of the literature on public perceptions of science seeks to look into a link between scientific literacy and knowledge and attitudes towards science (for example, Hayes and Tariq 2000, Bak 2001, Sturgis and Allum 2004). The "deficit model" advances that due to the "lacking a proper understanding of relevant facts, people fall back on mystical beliefs or irrational fears of the unknown" (Sturgis and Allum 2004: 57). However, Bak (2001) argues that, when it comes down to *controversial* scientific research, then one's education is not a determining factor regarding one's attitude towards science. These analyses contribute to support to the "intrinsic thesis" (cf. Nisbet et al. 2015) which attribute negative attitudes towards science to supposedly intrinsic characteristics such as intelligence or psychological traits. For example, Rizeq et al. (2020) consider anti-science attitudes as being "contaminated mindware" and, in the context of an experiment, associate them to low score on a scale of "Active Open-Minded thinking", that is one's propensity to take into consideration arguments and evidence that contradict one's initial position.

Research linking scientific literacy or knowledge, as well as general education, to anti-science attitudes has been vastly criticised. The main theoretical weakness of the scientific literacy hypothesis relies on the fact that it leaves aside the contextual factors that may affect anti-science attitudes. Social and institutional factors, as well as perceptions of risks linked to new technologies, are arguably more important determinants of individuals' attitudes towards science (Wynne 1991, Priest 2001). For example, in the case of attitudes towards vaccination, Blume (2006) argues that more and more educated parents oppose vaccination because they are dissatisfied with the available information and the attitudes of public health officials. He further contends that this may be the result of a reconfiguration of citizenship that puts more emphasis on personal rights and responsibilities. Likewise, Durbach (2002) has shown that the anti-vaccination movement amongst the British working class in the late 1800s mostly stemmed from the ruling class' disdain towards workers. So, while education or scientific literacy were most probably correlated to holding anti-vaccination attitudes, this doesn't mean there was a causal relationship between the two.

A second common criticism of the scientific literacy hypothesis relates to the way in which it is measured in surveys – which are the main sources of data used to support such claims. Scientific literacy is indeed often measured by asking "textbook" science questions to survey respondents, which are culturally situated and normatively selected (Peters 2000).

Scientists should be cautious when advancing rather essentialising – and fairly contemptuous – arguments suggesting that anti-science attitudes stemming from defence mechanisms are that of the uneducated and unintelligent. While Sturgis and Allum (2004) contend that "there is ample reason to consider it quite implausible that the well-informed and poorly informed citizens go about the business of making up their minds in the same way" (p.58); they do not offer any explanation as to why scientific literacy would play a role in this. Perhaps the contemptuousness of scientists, rather than scientific literacy, is a more important factor in leading the public to adopt anti-science attitudes.

III. Influencing anti-science attitudes: the role of elites in shaping (anti-)science

Anti-science attitudes are not solely an individual-level matter, various influential actors have played important roles in giving people good reasons to be sceptical of scientific evidence or institutions and have even straightforwardly encouraged anti-science attitudes. Before delving into the ways in which we can work to limit anti-science sentiments, it is essential to understand who and what influence general perceptions of scientific institutions, particularly in regard to the uncertainty, error, and corruption that may be involved in science. Four types of elite actors who may influence attitudes towards science have been underlined in the literature: industries, scientists, politicians, and medias.

3.1. Industrial elites

The denial of scientific evidence by industry groups to upkeep their business interests is a vast and rather well-documented topic – considering the fact that these powerful actors put a lot of effort into concealing these deceitful practices. This section presents some well-known cases illustrating such practices.

3.1.1. Manipulating evidence

The tobacco industry is often referred to as being a precursor in the manipulation of public opinion to create disbelief around the dangers scientists associated to the consumption of its products. Drawing on previously secret archives of tobacco groups in the United States, historian Robert Proctor puts into evidence the large-scale conspiracy of cigarette manufacturers, corrupt experts, and politicians who contested the carcinogenic risks associated to tobacco-smoking that scientists denounced (Proctor 2012). In a more recent study, Ulucanlar et al. (2014) identify some strategies used by the tobacco industry in the United Kingdom to delay or stop tobacco regulation that would impair their business: using “tweezers” and “mimicked scientific critique”, they cherry-picked evidence, borrowed scientific jargon, and hired fake experts to argue their case before legislators and attempt to discredit science showing the harmfulness of tobacco consumption. Similar strategies have been used by powerful industrial actors to contest climate science, notably that evidencing the risks associated to ozone depletion and acid rains, as well as their relationship to human, industrial activity (Oreskes and Conway 2010).

The manipulation of politicians and public opinion by industrial actors regarding the use of certain products has been quite extensively documented and discussed. It has caused important delays in public policymaking, entailing substantial public health and environmental risks. One particular domain over which industries have developed efficient and devastating strategies to preserve their economic interests is that of chemicals denial (Karlsson 2019). Ignoring public health and human rights, industrial groups have controlled, tweaked, and concealed much scientific research that led, amongst other things, to the wide use of lead in paints and pipelines despite its known disease-causing and even deadly effects (Micheals

2008, Markowitz and Rosner 2013). As they faced warnings from scientists regarding the harmful effects of some chemicals, industries have managed to shift the burden of proof upon these same scientists so as to be able to keep on using these products – infamous examples include lead and asbestos, but also mercury, bisphenol A, benzene, and vinyl chloride, amongst many others. By allowing this, administrations have and continue to have an important role in conceding to industrial lobbies as they place unreasonable expectations on science and scientists facing corporate giants (Oreskes and Conway 2010, Karlsson 2019).

Trust in policymakers, notably regarding environmental policies, is further eroded by the lobbying power of the Polluter-Industrial Complex (Faber 2009). Researchers are increasingly calling authorities to rely on the scientific studies of research institutions, rather than on studies that are carried out by industrial groups. Industrial actors have indeed been accused of "manufacturing uncertainty" to protect their economic interests by concealing information (Micheals 2008).

3.1.2. Disregarding evidence

Other noteworthy examples are that of medications that proved to have dangerous side effects and were commercialised under the pressures of pharmaceutical groups. In the 1960s, the benfluorex molecule was commercialised under the name of Mediator by Servier pharmaceuticals which presented it as a treatment for diabetes. The medication was initially developed to conquer the market of drugs against obesity, Servier sought to preserve the drug's anorexigenic properties – i.e. its appetite-suppressant effects – and rid it of its undesirable side effects. However, soon after, a study showed that the drug could diminish levels of lipids and sugar in the blood. After a short administrative struggle, Servier was able to commercialise the drug as a diabetes treatment. In the early 2000s, independent studies showed links between the use of Mediator and the development of cardiologic and pulmonary diseases. The medication was only withdrawn from the market in 2010, it is estimated to have caused in between 500 and 2000 deaths in France and over a thousand lawsuits have been filed. The Mediator affair is a clear example of how pharmaceutical marketing strategies, on the one hand, and the disregard of the principle of precaution by administrations, on the other hand, can have devastating effects in terms of public health (Morelle and Padis 2011), with repercussions on public trust.

A large number of scandals have put into light the dangerous practices that have been encouraged by industrial groups in a quest for profit. Scandals regarding the price of some medicines have also eroded the image of pharmaceutical companies: when the company Mylan bought the patent for the EpiPen, led a large lobbying campaign to make its use widespread, and increased its price sixfold; when Turing Pharmaceuticals brought up the price of Daraprim tablets from a dozen to hundreds of dollars; when Novartis put Zolgesma on the market, a 2 million euro shot to treat children's spinal muscular atrophy; and so on. In light of these scandals, it is all but surprising that the public view industrial groups as some sort of evil doers which only aim is to maximise profit, in spite of the entailed public health and environmental dangers. In a 2019 Gallup survey in the United States, respondents expressed their views concerning various industries on a Likert scale: 58% of respondents said that their view of the pharmaceutical industry was somewhat negative or very negative, making it the

worst viewed sector followed by the federal government (52%) and the healthcare industry (48%)[4]. Some medical practitioners have also become wary of pharmaceutical industries (see Desclaux-Arramond 2017).

Though it is so far a rather bleak picture of industrial influences over science and industrial anti-science that I have painted in this section, it is no cause for complete despair. In light of recent events, some commentators have formulated the hypothesis that trust in pharmaceutical companies may increase with the COVID-19 pandemic[5]. Some companies have indeed joined efforts with public research institutions in order to find a vaccine to treat the virus; others that are usually rivals have also started working together to achieve this same goal[6]. And this is reflected in public opinion according to an APCO poll in which three-quarters of respondents agreed with the statements that researchers across the world were working together to develop a vaccine and that both public and private sector actors were also joining forces to this end[7]. Perhaps this global pandemic is contributing to a re-articulation of private and public research initiatives. Perhaps this will limit the anti-science instrumentalisation of science by industrial elites, and hence the propensity to which it may foster anti-science sentiments. These possible reconfigurations of pharmaceutical research should be the object of future research.

3.2. Scientific elites

The new knowledges and techniques that are put forward by science and scientists are at the heart of the development of our modern societies, guided by a constant desire for the betterment of means of production and quality of life. But, in recent decades, various polemics – be they related to radioactivity, lead, asbestos, or medications – have brought before the public eye the uncertainties that exist within scientific evidence and postulates. The advancement and use of science and technologies has had effects on both public health and the environment that were unforeseen by those same scientists who made the discoveries leading to these changes. As such, it is essential to reflect on the role that scientific elites may play in the formation of anti-science attitudes.

3.2.1. Uncertainty and expertise in public policy formation

Science should not be trusted blindly. Scientists, all of whom are specialised in extremely specific areas, cannot anticipate every possible repercussion that the implementation of a particular policy will have on the biosphere, on societies, on categories of individuals. As

[4] Gallup (2020), "Big Pharma sinks at the bottom industry rankings", available: https://news.gallup.com/poll/266060/big-pharma-sinks-bottom-industry-rankings.aspx [22.09.2020].
[5] People with chemistry (2020), "Is COVID-19 changing perceptions of the pharmaceutical industry?", available : https://www.peoplewithchemistry.com/us/blog/thoughts/is-COVID-19-changing-the-public-perception-of-the-pharmaceutical-industry/ [22.09.2020].
[6] The Times (2020), "Glaxo teams up with French rival Sanofi to develop vaccine", available: https://www.thetimes.co.uk/edition/business/glaxo-teams-up-with-french-rival-sanofi-to-develop-vaccine-9wkk3glnw [22.09.2020].
[7] APCO Worldwide (2020), "COVID-19 Reminds Americans About the Value of Vaccines", available: https://apcoworldwide.com/wp-content/uploads/2020/04/APCO-COVID-Americans-Vaccines.pdf [22.09.2020].

such, it is important to understand the place of uncertainty in science and the ways in which it is managed.

Each time new knowledge is generated by science, new ignorance is also produced (Ravetz 1987). Philosopher of science Jerome Ravetz takes the examples of radioactivity: while new knowledge on the radioactivity of certain technologies and detritus has put into evidence its nefarious risks for both public health and the environment, it has also generated new ignorance in regard to how these should be managed. As such, science is not merely a source of knowledge, it advances our understanding of some of the workings of the world, while also highlighting those that go beyond our comprehension, those that we cannot even apprehend because we lack the appropriate tools. Science, beyond increasing knowledge, also makes us see some problems that we are unable to resolve. That is what Ravetz has called the "social construction of ignorance" (Ravetz 1987: 106). He differentiates "systems uncertainties", that is the "range of possible outcomes, corresponding to each set of plausible inputs and decisions", and "decision stakes" that correspond to the cost-benefit calculations of various parties that are involved (Ravetz 1987: 102). When both are low it is likely that a consensus be attained, but if one or both are medium to high, then debate of a polemical nature may emerge, with some parties opposing the application of new scientific discoveries.

In their capacity as experts, it is important to think the ways in which scientists manage uncertainty. And once again, past scandals put into evidence some structural inefficiencies and malfunctions in decision-making instances by highlighting the mismanagement of uncertainty by scientists and its effects. In the aforementioned Mediator affair, the scientists who were on official pharmacovigilance boards ignored the whistles that were being blown here and there by a few independent actors, whether because they had undeclared vested interests or because of some sort of corporate endogamy (see Troude-Chastenet 2011). As a result, the medicine was removed from the market years later, once the case had gained mediatic momentum and political salience. In a Weberian sense, this example prompts a reflexion over the distinction that should be made over the technical opinion or expertise of the scientist and the ethical discernment and decision of the politician. It is essential that the deontological rules requiring that scientists disclose any conflict of interest be respected and enforced (Morelle et Padis 2011). Perhaps it is also necessary that the involvement of scientists in public decision-making be revised so as to ensure the soundness of expertise.

3.2.2. Scientists in polemics

Scientists' approach to the management of uncertainty is also of interest outside of public decision-making instances, especially at a time when the circulation of information is exponential and virtually untameable – I will come back to this particular point a bit later.

Though the triggering of alarms by scientists has saved lives in the past – the Mediator affair is a prime example – it has also caused huge polemics that have contributed to the erosion of trust in science. For example, in a paper published in 1998 in British medical journal *The Lancet*, former doctor Andrew Wakefield claimed a link between the administration of measles, mumps, and rubella (MMR) vaccines and autism in young children. The study has

since then been declared as fraudulent in regard to its methodology and the claim has been vastly refuted by scientists (see Taylor, Swerdfeger, and Eslick 2014). The paper was eventually retracted by *The Lancet* in 2010. Nevertheless, the dangerousness of MMR vaccines is still a rather polemical topic as Wakefield's claims continue to be supported and diffused by anti-vaccinationist groups. Their influence over people's attitudes towards vaccination are believed to be at cause in recent measles outbreaks across the world (Benecke and DeYoung 2019). Whether Wakefield's claim was the result of an honest or malevolent effort is not the question here. Rather, what this example shows is the role that scientists can play in the creation of uncertainty and in its public saliency, engendering polemical debates and potentially nurturing defiant attitudes towards science and scientists. In this case, media framing also played an important part in making Wakefield's claim more visible than the retractions.

The recent polemic around the use of hydroxychloroquine to treat COVID-19 patients is another good example of the management of uncertainty by scientists and public health authorities in a climate of crisis. It was in part sparked by French doctor Didier Raoult who, after conducting an experiment on twenty-four patients in March 2020, claimed that hydroxychloroquine coupled to azithromycin treatment reduced the viral load of COVID-19 infected patients. In the midst of a sanitary crisis that has seen hundreds of thousands of deaths, the polemic caused the delayal of international clinical trials to find appropriate treatments against the virus as patients refused to be administered any other treatment[8]. In May 2020, *The Lancet* published and subsequently withdrew a paper that linked the administration of hydroxychloroquine to heightened mortality and cardiac arrythmia in COVID-19 patients. The lead author, doctor Sapan Desai, was already under investigation for professional faults, including allegations of data manipulation and fabrication. His co-authors later affirmed that they had never had direct access to the data the paper is supposedly based on. Several large-scale clinical trials later, the dispute is on its way to being settled: while chloroquine seems to limit the replication of SARS-CoV-2, which provokes COVID-19, in *in vitro* cell-cultures (Cortegiani et al. 2020), the sole administration of hydroxychloroquine appears to have limited *in vivo* efficacy (Ou et al. 2020). Notwithstanding, scientists from both sides of the debate played important roles in creating confusion and feeding a strongly polarising controversy at the time of a global pandemic. On the one hand, despite the fact that he could not substantiate his claims through rigorously scientific methods, Raoult put forward some evidence which he, as an expert, claimed to be scientific. On the other hand, Desai fabricated evidence in order to tame the polemic, it may be assumed. In both cases, scientists overstepped their roles as experts, making ethical decisions which influenced their supposedly technical opinion.

Scientists have sparked scientific polemics by understating[9] or overstating the uncertainty of some scientific findings. This may have been done so as to rid public perceptions of science

[8] Libération (2020b), "Le buzz sur la chloroquine freine l'essai clinique européen Discovery", available: https://www.liberation.fr/france/2020/03/26/le-buzz-sur-la-chloroquine-freine-l-essai-clinique-europeen-discovery_1783176 [16.07.2020].
[9] For another example, see Kaye (2015) about the FBI's pseudoscientific hair analyses.

of its aspect of uncertainty, in the former case, or to point out a scientific practice that was considered to be dangerous or insufficient, in the latter case.

Scientists have played important roles in sparking various polemics[10] that sometimes resulted in unfruitful debates, the paralysis of research processes, and may even have encouraged dangerous practices. It is important that deontological questions be individually and collectively re-examined by scientists in their research approaches. More debate is also needed on the management of uncertainty by scientists in the public sphere during and outside of crises, especially when it comes to the communication of their research – i.e. what is presented as science.

3.3. Scientific elites

The literature brings to attention two ways in which political elites may encourage anti-science attitudes: first, by becoming denialists themselves and therefore opinion leaders in science denialism; second, by creating doubt through a lack of transparency and incoherent discourses.

3.3.1. Politicians as denialists

Since the election of Donald Trump to the United States' presidency in 2016, science denial amongst government political elite has become a rather popular object of debate amongst political commentators. As a matter of fact, the last issue of *Engaging Science, Technology, and Society* includes a thematic collection of eight articles discussing anti-science under Trump. His administration's discourses are pseudoscientific in that its claims are substantiated by selective and non-replicable evidence and legitimated by borrowing some symbols and idioms from scientific authorities (Lynch 2020). It has also been argued that the Trump administration will have an important effect in the polarisation of science and knowledge production, and especially a polarisation in the political sphere in turn to climate change (Frickel 2020). As a result of the extreme polarisation of decision-makers, environmental policy making is substantially delayed. When a scientific matter is seized by a political actor, whether positively or negatively, it inevitably becomes politically charged (see Gauchat et al. 2017). The "Trump Era", characterised by "post-truth", "fake news", and "alternative facts", has sparked many a debate around the consequences of having an "anti-science" president. Some of the arguments that are put forward by commentators and scientists alike may be accused of being speculative or of being too politically charged, but that is only normal in a time when the debate crystalises important political tensions that exist within the country.

Anthropogenic climate change denialism is the most contemporary example of opposition to scientific consensus amongst political elites, it is however not the only one. AIDS denialism is the denial of the relationship in between HIV and AIDS, which existence is consensual amongst an overwhelming majority of scientists. In the early 2000s, AIDS activists in South Africa have accused its government of murder, for it refused to make antiretroviral treatments

[10] For another recent example, see this article on the 5G polemic in The New York Times (2019), "The 5G Health Hazard That Isn't", available: https://www.nytimes.com/2019/07/16/science/5g-cell-phones-wireless-cancer.html [24.09.2020].

available to seropositive patients (Baleta 2003). Thbao Mbeki, the country's president from 1999 to 2008, and Manto Tshabalala-Msimang, his Health Minister, have been accused of causing the death of 343,000 South Africans (Nattras 2007). Mbeki, who has lived in exile most of his life, denounced a regime of global apartheid, his denial of AIDS was not so much linked to the epidemic itself, but rather to the contestation of the racist, Western image of Africa and Africans (Mulwo et al. 2012). While under no circumstances does this clear out Mbeki's name, it does interrogate the history of the instrumentalisation of science to serve the interests of powerful actors and its relationship with perceptions of scientific discourses amongst certain groups of persons. Despite the large denunciation of the South African government's public health policies, and the fact that antiretroviral therapy was eventually made available in the country in spite of Mbeki's disapproval, AIDS denialism still pervades amongst some seropositive persons, in Sub-Saharan Africa like in other parts of the world (see Kalichman et al. 2010, Holt 2019), it is not merely a relic from the past.

When politicians become denialists themselves, or exhibit anti-science attitudes, then not only may they pose threats to public health and the environment, but they may also contribute to spreading such attitudes as opinion leaders. In years to come, we may be able to see the medium- and long-term effects that some current presidencies, such as that of Donald Trump in the United States, Jair Bolsonaro in Brazil or Alexandre Loukachenko in Belarus, have on individual and public attitudes towards science.

3.3.2. Politicians as denialists

Outright denial of scientific evidence by political elites is the most evident way in which they may influence anti-science attitudes. It is however not the only role they may endorse in their formation.

The month of August 2020 marked the seventy-fifth anniversary of the atomic bombing of Hiroshima and Nagasaki. This draws our attention to the history of the development of nuclear weapons, its current state, and the involvement of political elites. Nine countries in the world dispose of nuclear armament, all of which regularly engage in modernisation processes of their nuclear arsenal without formulating any alternatives or even consulting citizens or their representatives (Pelopidas, Anderson, and Cantoni 2017). Besides the blaring democratic issues that this observation entails, the relative secrecy that is maintained by government officials on the topic of nuclear armament prompts questions surrounding their control. According to Pelopidas (2019), history shows that the avoidance of nuclear incidents is not due to the control we exercise over these technologies, but rather of sheer luck. As such, citizens have legitimately expressed concern over the seemingly confidential and ongoing "arms race" that is being led by nuclear-equipped countries, and so in light of the insufficient knowledge and the lack of measures concerning the management of radioactivity (see Ravetz 1987). Though the saliency of nuclear issues is currently rather moderate, the lack of democratic control over questions such as nuclear power may well prompt defiant sentiments towards the authorities that manage them.

In the context of anti-vaccination attitudes, Balinska (2004) has argued that the erosion of trust in public health institutions may be linked to the fact that the concerned authorities have "too often insisted that 'there is no risk' when later the potential dangers materialised" (p.1339). This reasoning linking the lack of transparency on the part of authorities to the development of anti-vaccination attitudes could well be applied to the previous example of nuclear weapons. It also recalls a recent polemic that made the headlines of French newspapers around the use of mask to prevent the propagation of COVID-19. As France was going through of penury of masks, Prime Minister Edouard Philippe declared that the general public mostly had no use for them. The use of masks was later generalised and made compulsory in grocery stores, public transportation, and in the street in some cases. As a result of these contradictory discourses, an Odoxa poll revealed that 76% of French people thought that the government had lied to them to conceal a fault on their behalf[11] – i.e. the mask penury.

These examples illustrate how the perceived lack of transparency on the part of authorities may affect people's relationship to science, and hence anti-science attitudes. Discourses that appear to be incoherent and a lack of transparency in certain procedures may make people question the true intentions of science. In the case of nuclear armament, one may wonder whether nuclear science is really beneficial to society as a whole or if it just used to further the agendas of power-greedy elites.

Political elites have non-negligeable effects upon anti-science attitudes. Some have encouraged behaviours that go against the scientific recommendations – such as that of health professionals or environmental scientists – hence normalising and even officialising disregard of scientific evidence. The lack of transparency around the aims and the use of certain scientific technologies may also be at cause in the erosion of public trust in scientific institutions.

3.4. Media

Scientific uncertainty has become increasingly salient over the past years and it is not seldom the result of industrial, scientific, and political influences: the circulation of information plays an important role. As the main medium through which information is massively disseminated, media play a non-negligeable part in influencing attitudes towards science, by defining the saliency and reception of certain scientific issues. Not only do media selectively communicate information, but they also frame its circulation. The transformation of the means through which information is disseminated also has a significant part to play in the formation of anti-science attitudes.

3.4.1. Creating controversies: media framing of scientific discourses

As they vulgarise scientific debates or controversies, media may contribute to the enhancement of the general population's awareness over certain scientific issues, they may

[11] Odoxa (2020), "Les trois-quarts des Français pensent que le gouvernement leur a menti sur les masques", available: http://www.odoxa.fr/sondage/trois-quarts-francais-pensent-gouvernement-a-menti-masques/ [24.09.2020].

influence shifts in common sense, and hence to the "enlightenment" (Ravetz 1987: 106) of lay people concerning scientific matters. Selective media coverage may also contribute to the reinforcement of certain frames (Zaller 1992) against which we define our own positions.

In the context of anthropogenic climate change denial, Gauchat et al. (2017) write that "once scientific claims about climate change entre the public sphere, either through accounts in the news media or from elected officials, they become politically charged" (p. 298). Much like politicians may serve as opinion leaders, media can be "opinion managers" (Reymond 2018). As they select both the topics that are approached and the material that is being diffused, media give a certain account of reality that is not free from bias. Staying on the example of climate change, media may frame climate science as being controversial in scientific communities rather than consensual. As such, they "fram[e] anthropogenic climate change in terms of debate, controversy, or uncertainty" (Antilla 2005: 350), obliviating the large scientific consensus that exists over the question of its reality. As they *frame* scientific discourse, media also *create* scientific controversies – or rather controversies around scientific discourses. This is of course true of climate science, but also of other scientific discourses once they enter the public sphere. Concern has therefore been expressed over the corporate control of media (Bagdikian 2004, Chomsky 1989). For example, journalists have played important roles in "manufacturing doubt" as they relayed tobacco industry anti-science discourses and claims (see Stocking 2009).

Media coverage, especially when it is unequal and sensationalist and gives little space to scientific responses, can have substantial influences in the creation of controversies and therefore in the formation of anti-science attitudes. The aforementioned case of Andrew Wakefield's claim that MMR vaccines cause autism in young children is a good illustration of this phenomenon. The claim was rapidly seized by media outlets, as its controversial nature made it newsworthy, and became the basis of a polemic. Despite the fact that Wakefield's medical license was revoked for grave misconduct and that his paper was retracted by the journal that had published it, the MMR-autism polemic perdures as anti-vaccination activists and celebrities use mediatic platforms to circulate their claims, often based on anecdotal evidence (see Benecke and DeYoung 2019). Online media may accentuate and prolong such polemics as a result of increased sensationalism through the use of click-baits and the low control of published information.

Anti-science attitudes should also be understood in relation to media framing of certain scientific controversies, which they may sometimes even create by putting forward pseudoscientific or outrightly fraudulent claims. Conversely, they may contribute to general inaction over certain problems that are pointed out by scientist as they support issue-framing emanating from important political figures (see Jacobs and Johnson (2007) on media framing of AIDS in South Africa).

3.4.2. The internet and social media

Information circulation has been revolutionised by the widespread use of the internet. Transformations in regard to both information circulation dynamics and information integration processes in social media are trending topics in the literature.

Much alike with traditional media, online news consumption can contribute to reinforce pre-existing dispositions and positions. As a result of both "culturally biased searches" and "culturally biased assimilation" (Kahan et al. 2009, 2011), online media users tend to manage information they encounter so as to buttress their priorly held beliefs and preferences (Jenkins-Smith 2001). This is particularly relevant to understand information searches and assimilation through social media: as we follow persons and groups with whom we share affinities, be they hobbies, interests, or political preferences, we are rarely confronted to information that clashes with our own beliefs, rather the information we find tends to confirm and strengthen our own inclinations. As a result of this confirmation bias, people who already express sceptic attitudes towards public health authorities and scientific institutions are more likely to see anti-science content in their social media news feeds. Moreover, since individuals and groups may publish content on social media without any fact-checking, virtually any type of information may circulate, regardless of whether it is true or not. Social media have been particularly embraced by anti-vaccinationists, who for example use Facebook groups to disseminate stories about the dangers of childhood vaccination and which serve as "echo chambers" to other anti-vaccination groups (Chiou and Tucker 2018). Anti-science content has become more readily available, and in larger quantities, with the advent of the internet and the widespread use of social media as information wells.

Thanks to the internet, information has become more readily available to users. In just a few seconds, using any search engine, one can find a plethora of information regarding any scientific issue they have heard about. The free access and circulation of such information has double-edged effects. Taking the example of health, the internet has enabled patients to acquire more knowledge about any chronic disease they may be affected by and from there we have seen emerge a new type of patient: the "expert-patient". On the one hand, this presents an interesting opportunity for medical research as patients' perspectives could be integrated in the research process so as to make it more inclusive and comprehensive (see Elberse, Caron-Flinterman, and Broerse 2010, Boudier, Bensebaa, and Jablanczy 2012). In this optic, Sorbonne University in Paris has created a "Patients' University" which goal is to integrate expert-patients to the training of health professionals. On the other hand, the advent of patient-experts may have caused an erosion of the trust that people have in health professionals. It has indeed contributed to shifting the healthcare paradigm: since the analytical power of doctors is now shared with patients, the legitimacy of science and practitioners may be questioned (Kata 2012). Health information online is also an object of concern considering its variating quality (see Scheufele and Krause 2019), especially as it would seem that fake information would travel faster than true information online (Vosoughi et al. 2018). The internet is a particularly important tool for anti-vaccinationists who use institutional-sounding website names to share anecdotal evidence and social media to divulgate fake vaccine mishap stories (Kata 2012).

The internet and social media have changed many persons' relationship to science as they have completely reconfigured the traditional means through which scientific information circulates and given more amplitude to alternative discourses. More research is needed on emerging media environments, particularly in regard to the reception of fake scientific information by lay publics (see Scheufele and Krause 2019).

The literature giving insights as to how elites influence attitudes towards science, and hence anti-science attitudes, is plentiful. Media, both traditional and new, play an important role in the circulation of scientific and pseudoscientific discourses and in framing some debates as scientific controversies. The circulation of such information and discourses can also be encouraged by prominent political or scientific figures who may act as opinion leaders. Moreover, anti-science attitudes amongst elites, be they politicians or scientists, can become public health and environmental hazards when they exert an influence over public policymaking. Finally, historians have also established the role that some industries have played in the manipulation of scientific evidence, and therefore in the erosion of trust in science.

IV. Remedying anti-science attitudes: (re)building trust in science

4.1. Scientific institutions

The present responsibilities of scientific institutions to remedy anti-science attitudes are twofold: commitment to deontological rules in scientific practices must be visibly and credibly re-asserted and science must shed its seemingly rigid and impenetrable perimeter in order become more accessible to and regardant of the general public.

Much discussion is needed around the practical application of the principle of scientific precaution and about defining to whom belongs the burden of proof. For instance, when it comes to the commercialisation of medication, the burden of proof falls upon the pharmaceutical company that has developed the medication: it has to prove that its benefits outweigh its potential dangers. Even if some potential dangers were to be discovered after the commercialisation of said medication, then it should be the pharmaceutical company's responsibility to prove that benefits still outweigh side effects in light of these new parameters. However, as shown by the Mediator case discussed above, the burden of proof has occasionally been shifted upon those who pointed to undesirable and dangerous side effects after the commercialisation, and hence initial institutional approval, of a medication (Morelle and Padis 2011). In this case, basic deontological rules were not respected as several members of the committee in charge of evaluating the dangerousness of the medication did not declare existing conflicts of interest (*ibidem*). The Mediator affair is one of many that has affected the public trust in scientific institutions, it is crucial that scientists' commitment to deontological rules be re-asserted and that misconducts be sanctioned. Morelle and Padis (2011) furthermore suggest that commissions of experts be envisaged in a multidisciplinary perspective to include philosophers and sociologists, as well as patients and patients' organisations (also see Troude-Chastenet 2011).

In a logic of deconfining science and in light of the increasingly polemical debates around science in the public sphere, the idea of a "technical democracy" has been advanced so as to give some guidelines concerning the treatment of uncertainty in public policymaking (Callon, Lascoumes, and Barthe 2001). The idea is to move away from a delegative democracy – in which the management of the uncertainties generated by science is exclusively delegated to representatives and scientists – towards a dialogist form of democracy – in which laypersons are included in said management. It is indeed argued that the involvement of laypeople is essential for scientists to see beyond their laboratories and consider a whole other range of uncertainties that are associated with the advancement of knowledge and technologies. As such, it is suggested that the seemingly inexorable opposition that is made between scientists and profanes be not reiterated, but rather that these categories be decompartmentalised. For we now understand that science comes with its own load of uncertainty, technical democracy is envisaged as an active and open process that can be embraced to develop knowledge beyond its present dichotomous organisation, taking into account its socio-political acceptability and its economic costs by enlarging the perimeter of science-related discussion.

There appears to be a general consensus in the literature about the need to further include the general public to scientific institutions. Including patients and laypersons in scientific processes would not only limit the risks of reproducing past errors, but it would also contribute to improve trust in scientific institutions.

4.2. Science communication and education

Considering the chasm that exists between scientific elites and the general public, as well as the extent to which it may feed some anti-science attitudes, scientists ought to think the methods and the language they use to transfer scientific knowledge. The journals *Science Communication* and *Science Education* provide a plethora of issue-specific studies and of general thoughts regarding the valorisation of scientific methods and research in lay publics.

Some scientists advocate for a greater proximity of scientific communities and the general public in order to bridge the gap that exists between the two. For example, vaccine scientist Peter Hotez has become somewhat of a public figure in vaccine-promotion in the face of rising anti-vaccination concerns and advocacy. As a vaccine scientist, on the one hand, and the father of an autistic child, on the other hand, Hotez works to debunk some vaccine-related myths – particularly those linking MMR vaccines to autism in young children – by vulgarising scientific discourse explaining the genetical basis of autism, all the while sharing his personal experience raising an autistic daughter (see Hotez 2018). Experimental evidence suggests that when scientists emphasise a shared identity while communicating their work, then publics that share this identity tend to a positive reception of the scientist's discourse (Shultz and Fielding 2014, Seyranian 2014). Given that social identity may be a mechanism contributing to the diffusion and adoption of anti-science attitudes, it may by the same token be understood as an exploitable vector for the promotion of scientific discourses. Moreover, through emphasising similarities between scientists and laypersons, such strategies can enhance communication by blurring the stark line that seems to be drawn between the two groups. As such, the rehashing of scientific consensus may be counter-productive if scientists are perceived to be

disconnected from the public (see Hornsey and Fielding 2017), they should therefore reconsider the methods that are used in science education and the ways in which their work is diffused outside of scientific communities.

Scholars and commentators have formulated various practical recommendations to improve science communication and education. For example, it has been suggested that science communication become a systematic feature in the training of all scientists, regardless of their discipline, to provide new generations of scientists with the tools and the motivations to valorise their work in the eyes of the public (Hotez 2020). Making scientists aware of the stakes of science communication may be especially important in a context where outreach is unequal across disciplines (Johnson, Ecklund, and Lincoln 2013). Science communication may also be substantially improved through education, particularly in a time when the circulation of fake news and pseudoscientific discourses is reaching unprecedented highs. Raising awareness around the nature of scientific methods, both through formal education and scientific valorisation, may better perceptions of science and people's ability to distinguish pseudoscientific evidence and discourse from scientific ones (see Pigliucci 2010 for a discussion of the difficult distinction of science from pseudoscience). To this end, science education should be approached with the goal of endowing people with critical tools to think the world rather than the imposition of supposedly objective truths (Longbottom and Butler 1999). It has been suggested that journalists be trained to scientific journalism on a more systematic basis[12]. Medias, and hence journalists, play a crucial part in the reception of scientific discourses as they partly control its diffusion and its framing. Though peer-reviewing helps limiting the circulation of pseudoscientific material (see Dunlap 2013), various badly conducted studies have had severe consequences for public health in the past and scientific evidence has often been distorted to support fallacious reasoning (Peters et al. 2018).

Concluding remarks

Before the threats that are presented by anti-science attitudes, it is crucial that scientists confront both old and new challenges. Some efforts have been made to break down the barriers between scientific communities and the general public, through the integration of patients in medical training for example, so as to stress the real-life foundations of science and to avoid its disconnection from practical concerns. A contemporary and thorny issue science has to face is that of the ever-faster circulation of fake news which contributes to ingraining pseudoscientific discourses amongst the general public. It is urgent that scientists work on ways to better communicate their work with the goal of slowing down and eventually reverting this motion. As it provides elements to conceptualise anti-science attitudes, to appreciate the mechanisms and motivations for the adoption of such attitudes, and to grasp the role of elite in the making and diffusion of anti-science, the present literature review gives some insights to apprehend and to hatch present and future efforts to restore the epistemic power of science.

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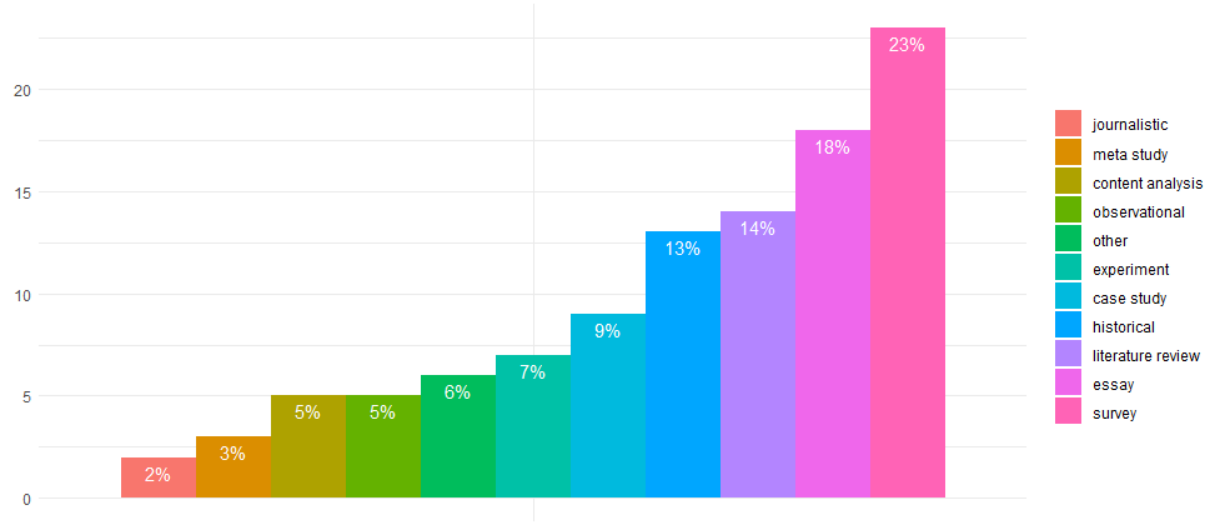
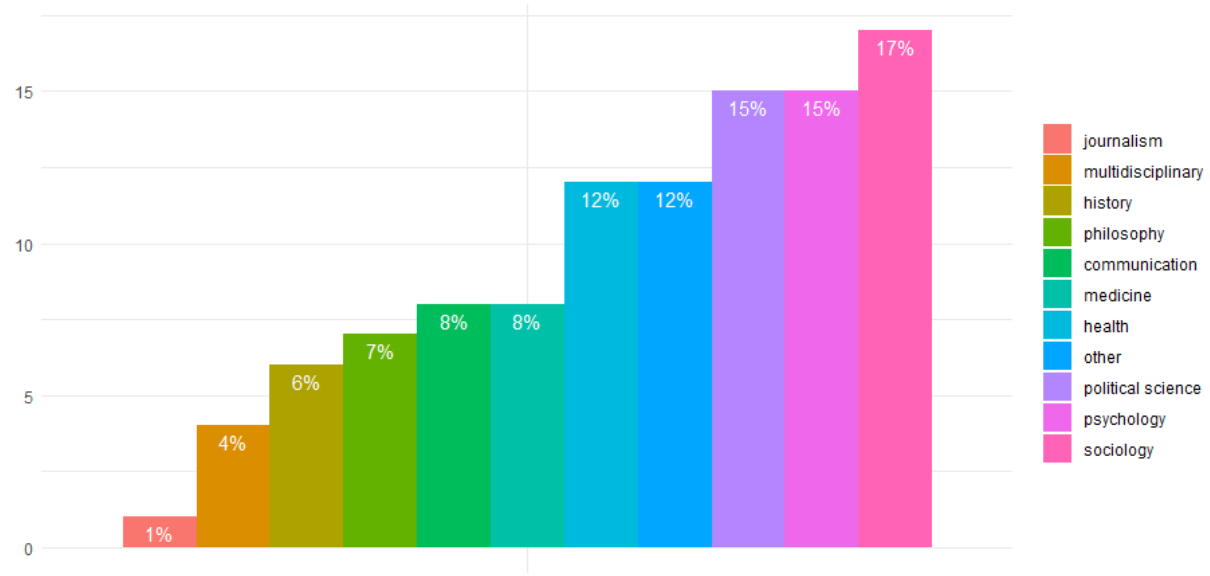
Appendix

Figure A1: Methods used in reviewed literature



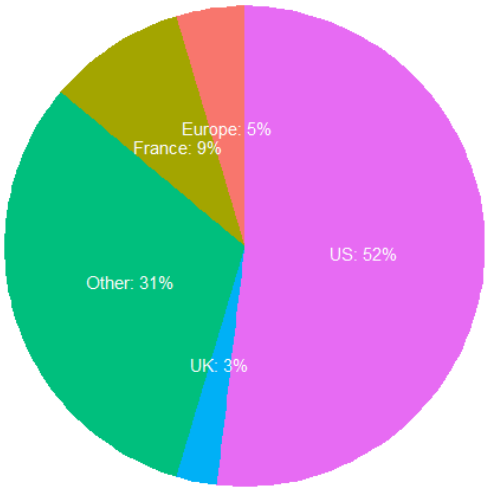
Note: This graph is based on the studies reviewed in this manuscript. It does not claim to reflect the share of methods in studies anti-science attitudes or discourse or science-scepticism in general.
How to read the graph: 2 per cent of the studies reviewed rely on journalistic inquiries, compared to 23 per cent that rely on surveys.

Figure A2: Disciplines of reviewed studies



Note: This graph is based on the studies reviewed in this manuscript. It does not claim to reflect the share of methods in studies anti-science attitudes or discourse or science-scepticism in general.
How to read the graph: 1 per cent of the studies reviewed belong to the discipline of journalism, compared to 17 per cent that belong to sociology.

Figure A2: Countries covered in reviewed studies



Note: This graph is based on the studies reviewed in this manuscript. It does not claim to reflect the share of methods in studies anti-science attitudes or discourse or science-scepticism in general.
How to read the graph: 5 per cent of the studies reviewed cover two or more European countries, while 52 of the studies cover the US.

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