Randomistas and Methodological Fetishism. Lessons From Covid-19 Pandemic

*Mattia Andreoletti**
mattiaandreoletti@gmail.com

ABSTRACT

It has now been more than a year since the start of the COVID-19 pandemic. Yet, despite the colossal and unprecedented scientific effort that has been put into it, many claims are still opaque, and many issues must be solved. Among these, one deserves the attention of philosophers of science: the scientific controversy about the theories of SARS-CoV-2 transmission. In this short paper, I analyze the debate between the droplet theory and the airborne theory of viral transmission. I argue that the acceptance of the droplet theory has been due to the philosophical commitments of the dominant scientific actors to a specific theory of evidence, which has become dominant in western democracies, and to a specific set of non-epistemic values, rather than to scientific considerations alone.

1. Introduction

> The Age of Professions will be remembered as the time when politics withered, when pretentious voters guided by professors entrusted to technocrats the power to legislate needs, the authority to decide who needed what and a monopoly over the means by which needs would be met (Illich 1977, p. 359)

As I am writing this paper (Spring 2021) COVID-19 pandemic is far from over, even though the situation seems to be improving thanks to a mass vaccination campaign. As everyone is almost certainly familiar with this topic – especially the readers of this special issue - there is no need to recapitulate the events that led to the outbreak and the following actions for mitigating it. So, with regard to this, the only thing worth mentioning in this introduction is that there has been a lot of uncertainty surrounding pandemic science since its beginning. And now, more than a year later, many claims are still opaque, and many issues have yet to

* Università Vita-Salute San Raffaele, Italy.

be solved - despite the colossal and unprecedented scientific effort that has been put into it (Wadman 2021).

Among the many issues that are yet to be solved, one may deserve the attention of philosophers of science: the scientific controversy about the theories of SARS-CoV-2 transmission. The theory of viral transmission is obviously a key knowledge in the management of the pandemic, as mitigation measures are taken precisely to interrupt the chain of the spread of the diseases. Of course, if the theory of viral transmission is wrong, policies will likely result ineffective or suboptimal. But, as we learned, preventive measures, such as lockdowns or school closures, may have tragic effects on society. Therefore, it seems very important that the scientific knowledge on which such policies are based is robust.

In this paper, I analyze the debate on two alternative theories of SARS-CoV-2 transmission: the droplet theory, and the airborne theory. And I argue that the acceptance of the droplet theory has been due to the philosophical commitments of the dominant actors to a specific theory of evidence, that have become dominant in western democracies, and to a specific set of non-epistemic values, rather than to scientific considerations alone.

Of course, this paper does not aim to directly contribute to the controversy between ‘droplet’ and ‘airborne’ scientists, but rather to offer a philosophical analysis of how the droplet theory came to be accepted by the scientific establishment. Therefore, the paper’s intended audience is not the scientists on either side, but the broader community of philosophers of science and scholars in social studies of science.

The structure of the paper is as follows. In the first section, I introduce the scientific basics of the debate, presenting scientific theories, evidence, and players. In the second section, I present the dominant theory of evidence in medicine and discuss its impact on policymaking. In the third section, I claim that, in general, the acceptance of a scientific hypothesis in medicine hinges also on a very specific set of non-epistemic values. In the fourth section, I argue that the droplet theory has been accepted because of (i) an uneven relationship of power and status between aerosol and droplet scientists, and (ii) a greater therapeutic value. Finally, I draw some general conclusions.

2. Droplet versus aerosol controversy

The controversy on SARS-CoV-2 transmission came to a boil with the publishing, in July 2020, of a letter from 239 scientists urging the WHO to amend its guidelines to recognize the airborne spread of SARS-CoV-2 (Morawska and Milton 2020).

The accepted theory of SARS-CoV-2 transmission is indeed the droplet theory. By "accepted" here I mean the theory that has led the official narrative of the pandemic, that has been endorsed by the World Health Organization (WHO) and national health authorities (e.g., CDC), and that has driven the mitigation strategies of most western countries. Public health interventions to contain the spread of the disease have been indeed introduced on the basis of this specific account. In a nutshell, according to the droplet theory of transmission route, people infected with COVID-19 emit viral particles during respiratory activities such as breathing, talking, yelling, coughing, sneezing, etc. The largest of these particles (i.e., the droplets) can travel up to about 2 meters, but then they fall to the ground since they are too heavy to travel further in the air. Within this range, these droplets can land in the mouths or noses of people who are nearby and infect them. Also, they can deposit and survive for some time on solid surfaces, which represents another crucial source of transmission. On the airborne account instead, the virus can travel far longer in smaller particles exhaled by infected people – the aerosol.

The WHO scientists did not accept the aerosol theory because the evidence supporting it was considered as "weak," and even now, even if more evidence is accumulating, they remain largely unconvinced and maintain that the research on aerosol transmission is still inconclusive. The droplet theory was developed originally by the American epidemiologists Charles Chapin in 1910 and it has been continued since then[1]. In the context of COVID-19, evidence for the droplet theories came mostly from old epidemiological studies, randomized controlled trials, and systematic reviews, demonstrating the benefits of masking (Cowling et al. 2010; MacIntyre et al. 2009), hand hygiene (Cowling et al. 2009), and surface cleaning (Levy et al. 2014), consistently with the predictions of the theory[2]. On the contrary, the evidence for the airborne transmission of

[1] For a well-informed historical account see (Randall et al. 2021).

[2] For an authoritative and updated list of references supporting the droplet theory and related interventions see the relevant WHO and CDC web pages; https://www.who.int/news-

SARS-CoV-2 comes from many different kinds of study, mainly from case reports such as detailed analysis of super-spreaders events, where several people get infected from a single contagious individual (see e.g., Lewis 2021; Liu, Eggo, and Kucharski 2020), but also form laboratory studies, especially animal studies (see e.g., Kutter et al. 2021; Sia et al. 2020).

The choice between these two theories has important implications for the public health policies to combat the pandemic. If the coronavirus disease spreads through droplets that fall within 2 meters, then the controls measure are like the following: reducing close contacts with physical distancing and physical barriers (e.g., plastic screens), hygiene washing, surface cleaning, and use of masks within droplet distance. Notably, such policies do not distinguish between indoor and outdoor because the gravity-driven mechanism of transmission applies to both scenarios. If the infection is instead airborne, people can get contagion even at a higher distance. Therefore, reducing the transmission of the virus would require different measures in order to avoid the inhalation of aerosols. These measures may include for instance: ventilation, air filtration, reducing time spent indoors, use of masks whenever indoors, and also special attention to mask filtering quality and capacity. Briefly, the airborne theory would mandate stricter, more difficult, more costly, and perhaps less popular, public health policies (Morawska et al. 2021).

In the next paragraphs, I am going to explore deeply this scientific debate through the lens of the philosophy of science. This seems to be a particularly interesting case, as it makes clear that sometimes a scientific hypothesis is not established on the basis of the available evidence and scientific reasons, but rather on some *a priori* considerations of what counts as scientific evidence and what values should be pursued.

3. Medical knowledge and evidence

Nowadays, everyone agrees that medical doctors should act in accordance with scientific evidence but disagrees about what evidence precisely is. The most common answer to this problem in medicine comes from the so-called Evidence-Based Medicine (EBM) movement, which since the 1990s has shaped clinical

room/commentaries/detail/modes-of-transmission-of-virus-causing-covid-19-implications-for-ipc-precaution-recommendations [accessed on 31st May 2012]; https://www.cdc.gov/coronavirus/2019-ncov/science/science-briefs/sars-cov-2-transmission.html [accesed on 31st May 2021] practice. For any hypothesis in medicine (e.g., regarding the effectiveness of an intervention) there is usually a large variety of evidence, stemming from very different sources and disciplines (from in-vitro and in-vivo research, observational studies, to case reports and individual experience of physicians). And sometimes these sources might even conflict with each other. To solve this disagreement, the EBM proponents have elaborated a very specific medical epistemology (see e.g., Guyatt 1995). They noted that, for the aims of medicine, not all kinds of evidence are equally valid. Scientific research is indeed prone to bias, and so we can rank the evidence according to its potential to prevent biases, and this potential depends eventually on the research design. Study designs that rank higher on the hierarchy of evidence are more likely to provide reliable evidence, as they can prevent more biases. Over the years, methodologists have identified a list of biases that can occur when experimenting and have agreed on a list of debiasing controls and procedures to be implemented (e.g., randomization, masking, etc.). From an ideal point of view, the methodology of RCTs can deliver more unbiased results, at least when compared to other kinds of studies. This is because there is more room to implement debiasing procedures in RCTs than in any other experimental design.

Therefore, the EBM theory of medical knowledge and evidence ranks scientific studies in a very rigid hierarchy, according to their quality. Meta-analyses, systematic reviews, and RCTs are at the top of the so-called "evidence pyramid". Whereas, surprisingly, mechanistic studies (i.e., laboratory basic research conducted in vitro and in vivo) are at the bottom, because they are deemed less valuable for clinical practice. In doing so, the EBM presents a normative argument about which types of evidence can be accepted as credible medical knowledge and inform medical decision-making. So, on the one hand, it is a theory of scientific knowledge. But, on the other hand, it also takes a normative stance on medical practice: wherever possible, medical decisions should be based on the best available evidence (i.e., RCTs) about the available interventions.

Despite its appeal, EBM continues to invoke many criticisms, but nonetheless it is still the dominant paradigm in the field, more than 20 years after its conception. The Evidence-Based framework has also extended its influence far beyond the medical field. The new millennium has seen indeed a huge increase of randomized studies basically in every scientific field especially those related to policy decision-making. The so-called Evidence-Based Policy (EBP) movement has enjoyed a rising success, especially in economics, culminating in the 2019 Nobel Prize awarded to some of its most prominent figures: Abhijit Banerjee, Esther Duflo, and Michael Kremer. The advocates of the EBP account, call for the incorporation of rigorous and robust scientific evidence in policy decision-making. Following their comrades in medicine, they identify RCTs as the most "scientific" or "rigorous" approach. Advocates of this account have been dubbed the "randomistas" (Leigh 2018), because of their instance on RCT as the "gold standard" of evidence. But their implications are even stronger than the "gold standard" claim: for the randomistas, RCTs are not just top of the hierarchy of evidence, actually there is nothing else in the hierarchy.

This view has come mostly from prominent academic economists, but it also has "permeated the popular discourse, with discernable influence in the media, development agencies and donors, as well as among researchers and their employers" (Ravallion 2020, p. 4). As a result, today the randomistas "rule" in the sense that they claimed hierarchy of evidence has now swayed the public opinion, and it is the foundation of their intellectual authority and power to persuade policymakers. Randomistas, including clinicians and epidemiologists, have indeed acquired greater legitimacy in informing our policies. While acknowledging that RCTs are indeed very informative for some purposes, many scholars argue that the supportive public narrative on RCTs that has emerged is not well-grounded in an appreciation of the limitations of this research tool.

As mentioned above, this account has indeed received many criticisms. For instance, philosophers of science (see e.g., (Andreoletti and Teira 2016; Ashcroft 2004; Cartwright 2010, 2011; Deaton and Cartwright 2018; Russo and Williamson 2007; Stegenga 2014; Worrall 2010) have challenged time and again the supremacy of RCTs (and the EBM epistemology) for assessing causality and evaluating interventions both in medicine and in social sciences, such as economics. However, such powerful criticisms have not yet made many breakthroughs among public opinion and policymakers. And randomistas continue to rule undisturbed. As Naomi Oreskes suggests in her seminal book "Why trust Science?", the stubborn focus on one method above all others is a kind of fetish. She indeed refers to the blind faith in randomized studies as methodological fetishism. "These are situations where investigators privileged a particular method and ignored or discounted evidence obtained by other methods, which, if heeded, could have changed their minds" (Oreskes 2019, p. 134). Evidence comes of course in many forms, some of them are imperfect but there are no compelling reasons to ignore them. In many contexts, for instance, the preferred methodological standard is unsuitable or difficult to meet, whereas other methods can deliver some important information as well: imperfect information is still information, and it seems silly to discard it because it does not meet some questionable philosophical precommitments about methodological quality. This "methodological fetishism" may lead some scientists to dismiss valuable forms of evidence just because they do not fit their methodological precommitments. With this regard, Oreskes goes even further claiming that "Science is at its weakest when it is governed by assumptions or becomes enamored with a particular theory or method to the extent it rejects contradictory results" (Denholme 2020, p. 121).

As a result, policy decision-making seems to be dominated by a cartel of scientists: the randomistas. Beyond methodological considerations, many other non-epistemic factors contributed to the success of randomistas from the early 1990s. For instance, researchers who did not use randomization started to be harshly criticized. And leading academic journals started to prefer randomized experiments for publication, at the expense of other study designs. Also, the leading randomistas did a very good job in convincing and teaching others how to use their preferred method. The rhetoric of randomization then reached also public attention and gained the support of major magazines and newspapers. So, it is not the methodological superiority of RCTs (there is probably none) that explains the success of randomistas even beyond academia, but rather the ability of its advocates to convince a sufficient number of stakeholders at the right time (Jatteau 2018).

4. Medical theories and therapeutic value

It goes without saying that the main aim of medicine is "caring and curing" patients (Stegenga 2018), usually intervening by "removing" the cause of the disease. If this is the case, then medical doctors need an understanding of basic concepts such as "health" and "disease" to identify who needs help, and more complex ones, such as "cause" and "evidence", to know how to intervene efficiently. Theories of health and diseases, as well as theories of evidence and medical knowledge, have significant societal ramifications since their content determines the treatment of an individual. Yet, while it is undeniably true that medicine is both a practical and social endeavor, it is at the same time a scientifically founded discipline. Then, in medicine, one can find theories in both a foundational and a special sense. Foundational theories lay the foundations of the discipline, while special theories aim at providing an account of observed phenomena.

Notably, unlike most other scientific fields, where theory is more detached from applications, both kinds of medical theories are tightly linked with practical action (understanding, treating, and preventing disease). In fact, medicine is subordinate to a fundamental ethical imperative, which demands action to assist people in case of sickness or accident. As of today, no other scientific discipline has even a smidgeon of the impact that medicine has on our everyday life.

For these reasons, medicine is deeply bound to a specific set of values that also define the epistemic aims of the field. Medical practitioners do not aim at a better understanding of phenomena, they do not want to uncover the nature of health and disease for the sake of increasing scientific knowledge but rather for the sake of caring and curing patients. And this makes particularly sense in light of the so-called ″therapeutic imperative″ (see Paul 2004; Pellegrino 1979; Rosenberg and Vogel 2017), which assigns different weights to medical theories according to their ability to support therapeutic practice.

Although the literature on value in science in the philosophy of science is endless (see e.g., Reiss and Sprenger 2020 for a comprehensive overview), very little philosophical effort has been put on values in medicine, much less on the role of non-epistemic values in adjudicating between competing medical theories. In this regard, however, the work of the historian of medicine David Jones is particularly enlightening. In his book "Broken Hearts: the tangled history of cardiac care" (Jones 2013) he describes the scientific controversy over what causes heart attacks. Since the beginning of the 20th-century cardiologists and pathologists have debated about the causes of heart diseases. Over the years, scientists have elaborated different theories (e.g., progressive obstruction, thrombus deposition, hemorrhage hypothesis, plaque rupture) and produced a great variety of evidence for each of them. Nonetheless, they needed almost a century to achieve a consensus on the plaque rupture hypothesis. In his detailed analysis of the controversy, Jones noted that the consensus was eventually achieved not on the basis of the scientific evidence – which is today still controversial - but because of the therapeutic value of the theory. By and large, all the alternative theories had indeed some sort of scientific support, and the debate over what causes heart attacks was largely an academic question. The plaque rupture hypothesis did not become relevant for clinicians until it was linked to powerful and popular new treatments. In fact, the plaque rupture hypothesis rises to prominence in the late 1980s and early 1990s, thanks to the development of new drug therapies, specifically statins and platelet inhibitors. The advent of these new drugs fostered the scientific consensus on plaque rupture because they proved to be effective in reducing heart attacks. And their mechanism of action was based on the plaque rupture hypothesis. So, that theory gets an indirect confirmation from large, randomized controlled trials, which as we said before are considered, in the circle of clinicians, the most rigorous scientific evidence. While until then most of the evidence for any causal hypothesis of heart attacks came from laboratory studies and case reports.

Data from RCTs play therefore a key role in forming medical beliefs about the physiology of disease, making clear that physicians also use knowledge of treatment outcomes to revise their theories about the causes of disease. This, therefore, creates a dynamic process – exclusive to health sciences, in which therapies deeply inform medical theories. Given the epistemic aims of medicine – care and cure, it may be no surprise that the treatments influence theoretical claims. But even though this may sound appropriate in principle, it can create some problems in practice.

As Jones notes (Jones 2013, pp. 109-110), since the impact of medical theories depends on the extent to which they are linked to therapeutics, physicians may select new ideas just on the basis of their therapeutic values, dismissing instead potential valuable ones. The mere existence of an effective treatment can alter our medical understanding of pathophysiology. And this of course has consequences on clinical and policy decision-making.

5. Reconsidering the controversy

As we have seen there are two competing theories of SARS-CoV-2 transmission. On the one hand, the droplet theory suggests that the respiratory virus is transmitted by large droplets produced during cough, sneezing, etc., that settle to the ground within 1–2 meters. On the other hand, according to the aerosol theory, the virus travels also in much smaller particles that can remain airborne for longer distances and time. As we know, the former theory has played a significant role in the management of the COVID-19 pandemics, driving most of the measures to reduce the spread of the disease. However, the available evidence has never been conclusive, and today is still controversial, with many studies supporting the alternative theory. So, it is hard to appeal only to scientific considerations to explain why the droplet theory has been maintained as the dominant paradigm.

As Trisha Greenhalgh (Greenhalgh et al. 2021; Greenhalgh, Ozbilgin, and Contandriopoulos 2021), one of the most active voices among aerosol scientists, has recently argued, the ″orthodox position″ (droplet theory) on SARS-CoV-2 transmission has been taken by infectious disease researchers, epidemiologists, and public health researchers: mostly scientists working in medical environments. And these scientists are usually aligned with the epistemology of Evidence-Based Medicine (EBM), which considers the evidence from laboratory studies (exactly the kind of evidence supporting the airborne theory) as "weak". While the airborne theory has been supported indeed by scientists working in different fields, such as physics, engineering, and chemistry, who are mostly extraneous with respect to that epistemology and usually adopt very different methodological standards. These "heterodox" scientists however did not have a primary role in the management of the crisis. This is because there is a clear uneven relationship of power and status between the droplet and aerosol scientists in the debate on COVID-19 transmission. Indeed, droplet scientists are "members" of the randomistas cartel, and as such, they have a large influence on policy decision-making, while the "heterodox" scientist are mostly outsiders.

Moreover, in the context of pandemic science, the droplet theory has to offer immediate, and relatively easy to be implemented, "therapeutic strategies" to combat the spread of the disease, mainly: masking, mandate, social distancing, handwashing, surface cleaning, plastic screens, etc. Many of these interventions proved to be effective in previous randomized trials on other respiratory diseases and get a confirmation in more recent trials on COVID-19. On the contrary, the aerosol theory would mandate a paradigm shift in the management of the pandemic. The aerosol theory implies indeed very different preventive measures, such as ventilation of indoor spaces, air filtering, uses of adequate masks, and reducing time spent indoors. However, the efficacy of these measures has yet to be demonstrated, and their rationale is based on either laboratory studies or at most on case reports. Also, this kind of interventions is very difficult to implement in the general population, especially in a short time and under public pressure. So, the aerosol theory has little therapeutic value when compared with the droplet theory. The promise of effective solutions to mitigate the pandemic certainly also contributed to the acceptance of the droplet theory by policymakers.

6. Conclusions

Recent evidence is suggesting that the aerosol theory may provide a more accurate description of the COVID-19 transmission route than droplet theory. Nonetheless, the scientific establishment is reluctant to abandon the official narrative and endorse the contribution of aerosol scientists.

In this short paper, I analyzed this controversy from the perspective of the philosophy of science. I argued that the acceptance of a medical theory depends on some philosophical commitments that scientists share about the quality of methods. This is because over the years a cartel of scientists, the randomistas, has gained largely influence over policy decision-making. Moreover, I argued that medical scientists tend to select those theories that have greater therapeutic values. However, both these behaviors are grounded on *a priori* considerations that may be questionable, as philosophers and historians of science have shown time and again.

From this analysis, a few general conclusions can be drawn. First, methodological fetishism seems to hinder interdisciplinarity work. Pandemic is by definition a multidisciplinary problem, but so far it has been put just in the hands of the randomistas, clinicians, and epidemiologists, that define and control what counts as rigorous evidence. As such, they excluded the contribution of scientists working in different fields and aligning with different epistemology and methodological standards. The dominant theory of evidence and knowledge should therefore be amended in order to face complexity and interdisciplinary research that is fundamental to cope with issues of modern societies, such as pandemics.

Second, the power dynamics between scientific groups are a key factor in the acceptance of medical theories. But the fact that randomistas are ruling the policy decision-making is contingent, and their authority is not well-grounded in the epistemology. In this regard, discarding evidence coming from studies ranked lower in the hierarchy of evidence is also a way to enforce their standards and to reinforce their legitimacy to rule, but this has little to do with scientific considerations.

Third and finally, the acceptance of medical theories depends also on considerations about non-epistemic values. Medical scientists tend to prefer hypotheses that have a greater therapeutic value. While this may seem appropriate in theory, in practice can be often problematic.

REFERENCES

Andreoletti, M., Teira, D.. (2016). Statistical Evidence and the Reliability of Medical Research. In *The Routledge Companion to Philosophy of Medicine*, Routledge.

Ashcroft, R. E. (2004). Current Epistemological Problems in Evidence Based Medicine. *Journal of Medical Ethics* 30(2): 131–35.

Cartwright, N. (2010). What Are Randomised Controlled Trials Good For? *Philosophical studies* 147(1): 59–70.

Cartwright, N. (2011). A Philosopher's View of the Long Road from RCTs to Effectiveness. *The Lancet* 377(9775): 1400–1401.

Cowling, B. J. et al. (2010). Face Masks to Prevent Transmission of Influenza Virus: A Systematic Review. *Epidemiology and Infection* 138(4): 449–56.

Cowling, B. J. et al. (2009). Facemasks and Hand Hygiene to Prevent Influenza Transmission in Households: A Cluster Randomized Trial. *Annals of Internal Medicine* 151(7): 437.

Deaton, A., Cartwright, N.. (2018). Understanding and Misunderstanding Randomized Controlled Trials. *Social Science & Medicine* 210: 2–21.

Denholme, S.. (2020). Some Studies Are More Equal than Others. *Nature Physics* 16(2): 121–121.

Guyatt, G. H. (1995). Users' Guides to the Medical Literature: IX. A Method for Grading Health Care Recommendations. *JAMA* 274(22): 1800.

Illich, I.. (1977). Disabling Professions: Notes for a Lecture. *Contemporary Crises* 1(4): 359–70.

Jatteau, A.. (2018). The Success of Randomized Controlled Trials: A Sociographical Study of the Rise of J-PAL to Scientific Excellence and Influence. *Historical Social Research Historische Sozialforschung Vol. 43* No. 3.

Jones, D. S. (2013). *Broken Hearts: The Tangled History of Cardiac Care*. Baltimore: Johns Hopkins University Press.

Kutter, J. S. et al. (2021). SARS-CoV and SARS-CoV-2 Are Transmitted through the Air between Ferrets over More than One Meter Distance. *Nature Communications* 12(1): 1653.

Leigh, A.. (2018). *Randomistas: How Radical Researchers Are Changing Our World*. New Haven: Yale University Press.

Levy, J. W. et al. (2014). Increased Hand Washing Reduces Influenza Virus Surface Contamination in Bangkok Households, 2009-2010. *Influenza and Other Respiratory Viruses* 8(1): 13–16.

Lewis, D.. (2021). Superspreading Drives the COVID Pandemic – and Could Help to Tame It. *Nature* 590(7847): 544–46.

Liu, Y., Eggo, R. Kucharski, A.J.. (2020). Secondary Attack Rate and Superspreading Events for SARS-CoV-2. *The Lancet* 395(10227): e47.

MacIntyre, C. R. et al. (2009). Face Mask Use and Control of Respiratory Virus Transmission in Households. *Emerging Infectious Diseases* 15(2): 233–41.

Morawska, L. et al. (2021). A Paradigm Shift to Combat Indoor Respiratory Infection. *Science* 372(6543): 689–91.

Morawska, L., Milton.D. (2020). It Is Time to Address Airborne Transmission of Coronavirus Disease 2019 (COVID-19). *Clinical Infectious Diseases*: ciaa939.

Oreskes, N.. (2019). *Why Trust Science?* Princeton, NJ: Princeton University Press.

Paul, C.. (2004). The Relentless Therapeutic Imperative. *BMJ* 329(7480): 1457–59.

Pellegrino, E. D. (1979). 10. The Sociocultural Impact of Twentieth-Century Therapeutics. In *The Therapeutic Revolution*, eds. Morris J. Vogel and Charles E. Rosenberg. Philadelphia: University of Pennsylvania Press. https://www.degruyter.com/document/doi/10.9783/9781512819151-011/html (May 30, 2021).

Randall, K. et al. (2021). How Did We Get Here: What Are Droplets and Aerosols and How Far Do They Go? A Historical Perspective on the Transmission of Respiratory Infectious Diseases. *Interface Focus* 11(6): 20210049.

Ravallion, M.. (2020). *Should the Randomistas (Continue to) Rule?* Cambridge, MA: National Bureau of Economic Research. http://www.nber.org/papers/w27554.pdf (May 29, 2021).

Rosenberg, C. E,, Vogel, M.J.. (2017). *The Therapeutic Revolution: Essays in the Social History of American Medicine.* http://www.degruyter.com/doc/cover/9781512819151.jpg (May 30, 2021).

Russo, F., Williamson, J.. (2007). Interpreting Causality in the Health Sciences. *International Studies in the Philosophy of Science* 21(2): 157–70.

Sia, S.F.et al. (2020). Pathogenesis and Transmission of SARS-CoV-2 in Golden Hamsters. *Nature* 583(7818): 834–38.

Stegenga, J.. (2014). Down with the Hierarchies. *Topoi* 33(2): 313–22.

Stegenga, J.(2018). *Care and Cure: An Introduction to Philosophy of Medicine*. Chicago: The University of Chicago Press.

Wadman, M.. (2021). 'I'm Empty.' Pandemic Scientists Are Burning out—and Don't See an End in Sight. *Science*. https://www.sciencemag.org/careers/2021/03/i-m-empty-pandemic-scientists-are-burning-out-and-don-t-see-end-sight (May 29, 2021).

Worrall, J.. (2010). Evidence: Philosophy of Science Meets Medicine. *Journal of evaluation in clinical practice* 16(2): 356–62.