Epidemiology as Interventionist Science: Covid-19 and Its Non-pharmaceutical Measures

CM	Clinical Medicine
EBM	Evidence-Based Medicine
MM	Modern Medicine
CDCP	US Centers for Disease Control and Prevention
MERS	Middle East Respiratory Symptoms
NSAIDS	non-steroidal anti-inflammatory drugs
PE	Pyramid of Evidence
PHEIC	Public Health Emergency of International Concern
RCT	Randomised Controlled Trial
SARS	Severe Acute Respiratory Syndrome

Introduction

This contribution does not deny that Medicine is a healing art. However, Modern Medicine (MM) claims to be scientific. MM is said to cover two large domains of study and investigation – Clinical Medicine (CM) and Epidemiology.

CM deals primarily with the examination, diagnosis and treatment of patients; however, its scientific basis, today, goes beyond the mere clinical experience of the doctor and rests upon the knowledge contributed by biomedical sciences, biomedical research, genetics, not to mention medical technology in the diagnosis, treatment and prevention of disease and injury, typically using pharmaceuticals and/or surgery. In this complex array of knowledge standing behind doctors in their encounters with patients, they would be bearing in mind the so-called Pyramid of Evidence (PE), of which there are numerous versions, but the one which is the simplest and the most relevant for the thesis examined here is reproduced in Figure 1 below: As one can see at a glance, the highest quality of evidence presented is provided by randomised controlled trials (RCTs) as they score highest in accordance with the two criteria of probity invoked, namely, quality of evidence and risk of bias.[1] It stands to reason that medical knowledge which is arrived at through RCT experiments would be considered to be the most reliable.[2] Let us, for the purpose of this exploration, call Systematic Reviews and RCTs Level l-1 and Level l-2 respectively.

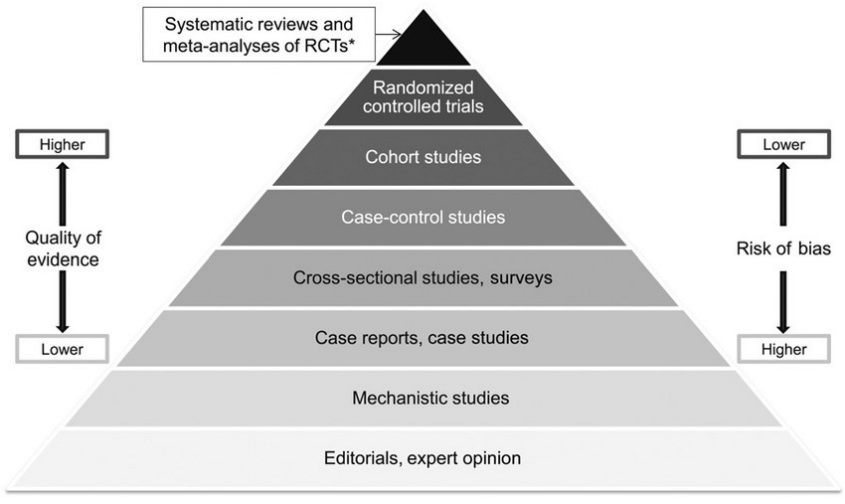

Figure 1 Pyramid of Evidence[3]

[1] Systematic reviews and meta-analyses are dependent on RCTs and hence are derivative from RCTs. This version of PE fails to mention EBM which also ultimately rests on RCTs. In that sense, EBM belongs up there at Level l: "EBM integrates clinical experience and patient values with the best available research information". 2008. – https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3789163/ .

[2] This not the place to examine critically the high standing of RCTs in this pyramid – see Lee in Bluhm 2017.

[3] Unfortunately, this downloaded image mentions no source which one could acknowledge.

PE is designed in such a way that RCT, *ex-hypothesi*, takes pride of place. As Epidemiology conducts no RCTs, epistemologically, it cannot hope to attain the status of probity enjoyed by knowledge derived from investigation ultimately using RCT methodology. Epidemiology relies on Cohort Studies, Case-control studies and Cross-sectional studies – these may be called respectively Level ll-1, Level ll-2 and Level ll-3.[4] The last is considered as belonging to Observational Epidemiology while the former two are said to fall under Analytic Epidemiology, which also includes a whole array of non-pharmaceutical procedures used extensively during the current pandemic called Covid-19 which is caused by the virus SARS-CoV-2, such as hand-sanitising/washing, mask-wearing, keeping physical and social distancing including self-isolation, test-track-trace[5], and national or regional lockdown.

This paper intends to explore the relationship between CM via RCTs on the one hand and Epidemiology on the other under two main aspects:

(a) It considers the obvious essential differences between a domain of MM in which RCTs can and do operate and that domain of MM whose goal and aim do not and cannot accommodate the RCT methodology, namely, Epidemiology.

(b) However, in spite of such radical differences, they do share something in common, namely, their goal is to find a means by which they each can respectively control the course and extent of harm a disease may inflict on people, whether as individuals or as a population of individuals. In that sense, they are both engaged in finding a factor, the control of which makes a difference to the outcome. In this spirit, each may be said to embark on an "experiment" looking for what may be called a "cause" in Collingwood's understanding of cause. In the course of this exploration, another philosopher would be leant on, namely, Mackie.

At this stage of the presentation, it may be appropriate to spell out in slightly greater detail how this paper interprets the activity of doing medicine and of its function in society.

1. The goal of MM is to cure and/or prevent/eliminate disease-generating conditions, suffering and death in an individual or within a population or populations in society.

2. Cure and/or prevention are used depending on the context of investigation. In some contexts, a pharmaceutical drug, found effective via RCTs, will be used to eliminate/control the disease. In others, pharmaceutical products, either as pills or vaccines, are not available. Or if available, their cost may mean that affected populations cannot afford them.[6]

3. In yet other contexts, RCTs are neither ethical nor feasible to mount.

4. When above limitations obtain, non-pharmaceutical measures alone are available to control/contain if not eliminate the disease-generating condition.

5. However, measures, whether pharmaceutical or non-pharmaceutical, are deliberate interventions to control/prevent the disease-generating condition. MM is, therefore, **Interventionist Science**.

6. Interventionist Science selects as "cause" a variable out of a complex of variables/factors, which if executed, could control/eliminate the disease-generating condition. This is Collingwood's analysis of cause as Sense II.

7. If above survives critical scrutiny, this would challenge and could revise PE. May be the very concept of the PE has to be abandoned, as it might make no sense to indict a knowledge claim as sub-standard when given the nature of the subject matter investigated, it could not satisfy the methodological requirement demanded of it. In any case, closer examination of the two types of investigation and intervention reveals a much more nuanced account of how disease and suffering/death may be ameliorated by relying on the methodological procedures of RCT (in CM) and Epidemiology.

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[4] For a critically-assessed account of the three types of studies, see Mann 2003.

[5] For one version of how this works, see Ridge 2020.

[6] The availability of vaccines against Covid-19 since the end of last year and the beginning of this makes the point only too clearly – while rich countries could order in advance and over-stock supplies for their people, poor nations have not the economic means to buy them or indeed even to get into the queue for supplies. https://uk.news.yahoo.com/funding-vaccines-sought-g20-nations-123351813.html?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuYmluZy5jb20v&guce_referrer_sig=AQAAALxF-Bt9AyBDQEPayIK7stSgU8I-chTGNNBZjsS8k0s-eQZxmK15XyyXHL_YEGbwcIgM6i1dvBN_GzgyRWPKuKZniA22C8LUVxGi-WtED-WTQxdalmlcc_CufFCvlaN9sy0hbcT1UET1XTC9_vbMq9YY1iSv5hr9JzMxn_H9YqQUMJB .

We need to explore, next, two conceptions of cause which may be helpful in throwing light on the aims of MM in its two main domains of practice and theory.

Mackie and Collingwood: their respective analysis of cause

The Australian philosopher, J. L. Mackie (1917-1981)[7] argued that a certain effect E, given plurality of causes, can be brought about by several distinct clusters of factors ((A + B + C → E), (D + F + $\bar{G}$ → E), (X + Y + Z →)) . Each cluster is sufficient to bring about the effect, but none of them is necessary. It is simplistic to understand cause as necessary and sufficient conditions. Consider the following example: A fire in a house. This particular fire was caused by a short circuit. All the same, the fire would not have occurred but for the presence of other conditions, such as atmospheric oxygen, inflammable material. Consider another incident which involves also a fire in a house. This time, an arsonist had poured petrol over the house, set it alight. Although each single factor in each incident is related to the effect E in a very important way, it is best characterised as follows: it is insufficient but non-redundant part of an unnecessary but sufficient condition for E. Each factor is called an INUS condition – "INUS" stands for "an insufficient but necessary part of an unnecessary but sufficient complex".

Take this example from CM, the discovery of the bacterium *Helicobacter pylori* by Warren and Marshall as the cause of peptic ulcer,[8] for which they were awarded the Nobel Prize in Medicine in 2005. Koch, a pioneer who ushered in the Age of Bacteriology, analysed the notion of cause (of a disease) as being "natural, universal and necessary". The bacterium is natural, alright. What does "universal" mean? Could it mean: whenever the disease occurs, the bacterium is present? This means that the presence of the bacterium is a sufficient condition for the disease. However, empirical evidence does not bear this out. According to the US Centers for Disease Control and Prevention (CDCP), two-thirds of the world's population have *H. pylori*; 90 per cent of people known to possess the bacterium do not have peptic ulcer, only 10 per cent do in its presence. If such data throw doubts on the claim that the bacterium is a sufficient condition of peptic ulcers, how about Koch's other claim that it is a necessary condition? Empirical evidence again fails to support this claim, as there are people who have no *H. pylori* and yet develop peptic ulcer. These are people who take over-time to relieve pain, drugs such as ibuprofen, aspirin, naproxen, collectively known as NSAIDS, non-steroidal anti-inflammatory drugs.[9]

In what sense, then, can *H. Pylori* be said to be the cause of peptic ulcer if it is neither a necessary nor a sufficient condition? Perhaps, it is best to regard the bacterium as an INUS condition. Should Warren and Marshall be given the Nobel Prize for just simply having discovered an INUS condition of peptic ulcer? It could have been but there may be something else which the Nobel Committee, sub-consciously if not consciously, have been looking for. On one obvious level, one could say that the Nobel Committee was impressed by the fact that these two researchers conducted (double-blinded) RCTs in 1985 and 1986, following their announcement in 1984 that they had found a strong correlation between *H. pylori* and peptic ulcer. The trial involved a hundred patients with peptic ulcer, divided into four groups. Each group was randomly assigned a treatment as follows:

(i) cimetidine, (ii) bismuth, (iii) tinidazole (an antibiotic), (iv) a placebo.

The results of this trial after ten weeks were as follows: (a) the ulcer healed in 92 per cent of patients, with *H. pylori* no longer detected, (b) the ulcer healed in only 61 per cent of patients with persistent *H. pylori.* After twelve months, 84 per cent of patients with persistent *H. pylori* relapsed, whereas only 21per cent of patients without continuing *H. pylori* relapsed. After seven years, 20 per cent of patients with *H. pylori* infection, but only 3 per cent of patients without the infection had ulcer.

Some American researchers conducted another trial between 1988 and 1990 with equally encouraging results. These sets of results were impressive but not enough to convince everybody, as sceptics claimed that it was bismuth which could have cured the patients of the ulcer and not the eradication of *H. pylori* which had done the trick. This time, Austrian and Dutch researchers conducted further trials which showed that it was the antibacterial drug which eradicated *H. pylori*, rather than the bismuth and antacids which were crucial in healing the ulcer.[10] By 1994 in the light of these tests, a consensus had emerged which held that *H. pylori* causes peptic ulcers (p), and that peptic ulcers can be cured by antibiotics (q). This consensus was set out in a document issued by the NIH (National Institutes of Health, USA).[11]

[7] Mackie was celebrated for his contribution to meta-ethics.
[8] Speaking strictly, *H. pylori* is the cause of gastroduodenal diseases, including gastritis, gastric cancer.
[9] See *Medical News Today* 2017; http://www.nutramed.com/digestion/ulcer.htm.
[10] For details, see Thagard 2000, 56-64.
[11] See Helicobacter pylori in peptic ulcer disease. *NIH Consensus Statement*, 1994 Jan 7-9; 12(1)1-23. URL = http:// consensus.nih.gov/1994/ 1994HelicobacterPyloriUlcer094html.htm .

According to the medical community, what is the relationship between (p) and (q)? Are they separate factual claims which are strongly but, nevertheless, merely contingently related? The NIH Development Panel (1994, 66) stated that:

> the strongest evidence for the pathogenic role of *H. pylori* in peptic ulcer disease is the marked decrease in recurrence rate of ulcers following the *H. pylori* eradication of infection.

Thagard 2000, 62, following the NIH, similarly holds that (q) is simply very strong evidence for (p).

> By far, the most impressive evidence that *H. pylori* causes peptic ulcers is the demonstration that eradication of *H. pylori* strongly contributes to the elimination of ulcers and the prevention of their recurrence.

However, they may not be totally right; the relationship between (p) and (q) is not quite such a simplistic matter, as (q) appears not merely to provide strong evidence in favour of (p). On the contrary, (q) is about controllability/elimination and constitutes a criterion of what counts as "cause" in (p). As a matter of fact, what Thagard says – see 2000, 61 – appears to be inconsistent with what he says a page later, as quoted above. On the earlier page, he has constructed Table 4.1, headed "Criteria for Causation", a schema he has adapted from Evans 1993, 174. This set has ten criteria, of which the 8th and the 9th are germane to our concern here (Thagard 2000, 61):

> 8. *Elimination or modification* of the putative cause or of the vector carrying it (e.g., via control of polluted water or smoke or removal of the specific agent) should decrease incidence of the disease.
> 9. *Prevention or modification* of the host's response on exposure to the putative cause (e.g., via immunization, drug to lower cholesterol, specific lymphocyte transfer factor in cancer) should decrease or eliminate the disease.

If *H. pylori* can be eliminated (via the antibiotic, tinidazole), significantly lowering the incidence of peptic ulcers, then *H. pylori* is "the cause" of peptic ulcers. This means that, *au fond*, controllability/elimination is used to single out one of the INUS conditions as "the cause" of the disease. This criterion is a potent one – medicine is in the business of relieving pain and controlling and/or eradicating disease. While theoretical understanding – what type of bacterium is *H. pylori*, its ability to live in a, by and large acid, environment in the stomach, its exaggerated release of gastrin in the stomach and its effects on the parietal cells, its increase of acid secretion, etc. – is all very gratifying, but the clinching argument for *H. pylori* being "the cause" of peptic ulcer remains the fact that it can be eradicated and that its eradication in turn leads to the healing of the ulcer and the lesser rate of relapse.

To reinforce the points made, we shall next explore in some detail the philosophical background of the notion of cause in terms of controllability, turning to yet another unlikely philosopher, R. G. Collingwood (1889-1943), noted as an archaeologist but interested in the philosophy of history and the philosophy of nature. We focus here on his 1938 paper on causation (address to the Aristotelian Society). He distinguished between three senses of "cause," of which the second (Sense II) is precisely about controllability. He also specifically mentioned that it is this understanding of cause with which medicine is most pre-occupied. We reproduce here some key passages:

> In Sense II … the word cause expresses an idea relative to human action; but the action is an action intended to control not other human beings (such as in Sense I), but things in "nature," or "physical" things. In this sense, the "cause" of an event in nature is the handle, so to speak, by which we can manipulate it. If we want to produce or to prevent such a thing, and cannot produce or eliminate it immediately (as we can produce or prevent certain movements of our own bodies), we set about looking for its "cause." The question "what is the cause of an event y?" means in this case "how can we produce or prevent y at will?" This sense of the word may be defined as follows. *A cause is an event or state of things which it is in our power to produce or prevent, and by producing or preventing we can produce or prevent that whose cause it is said to be.* …
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> Suppose someone claimed to have discovered the cause of cancer, but added that his discovery though genuine would not in practice be of any use because the cause he had discovered was not a thing that could be produced or prevented at will. Such a person would be universally ridiculed and despised. No one would admit that he had done what he claimed to do. It would be pointed out that he did not know what the word cause (in the context of medicine, be it understood) meant. For in such a context a proposition of the form x causes y "implies the proposition" x is something that can be produced or prevented at will" as part of the definition of "cause." For in such a context a proposition of the form "x causes y" implies the proposition "x is something that can be produced or prevented at will" as part of the definition of "cause." (pp 89-90)

Let us admit straightaway that Collingwood has, unfortunately, undermined his claim through over-stating it. Instead, one could more modestly say, on his behalf, that Medicine does not engage in theoretical investigation

out of pure intellectual curiosity; theoretical discoveries about the nature of cancer cells are predicated on the assumption that they have implications for new possibilities of treatment, cure, and/or prevention of cancer. Then, what Collingwood had said would sound neither silly nor outrageous. Collingwood would be wrong only if he meant that Medicine is nothing but the search for effective treatments/cures always empirically, by trial and error; that it has no legitimate interest in obtaining theoretical knowledge and understanding about the conjunction of factors (INUS conditions) leading to diseases. The truth which Collingwood had ignored and hence failed to emphasise is that Medicine has a foot in both the scientific/theoretical and the therapeutic camps.[12] Increasingly, new therapies in Medicine are expected to come from basic theoretical breakthroughs in the medical/biological sciences. For instance, the Human Genome Project and related basic sciences such as molecular biology/genetics are expected to play this critical role in the near future. However, for our discussion here of cause in terms of the controllability criterion, we can simply ignore this aspect of Collingwood's, admittedly, somewhat one-sided account of Medicine.

In any case, he correctly pointed out that this sense of cause belongs to practice, not theory. It belongs to what Aristotle called "practical science", where knowledge is not valued, primarily out of intellectual curiosity but utility. It also sits comfortably with the Baconian view of science that knowledge is power, nature is conquered by obeying her and with the overall ideological goal of the Modern Project of Science/Medicine, to use Science to manipulate/control nature to suit our purposes. Hence, built into this sense of cause, is the idea that cause and effect are related in the way means and ends are related. When we single out an INUS factor as the cause, we are saying that, in the practical/therapeutic context, it is the means by which we achieve the end of eradicating/ameliorating something deemed undesirable (pain/discomfort/death generated by disease). The relationship between means and ends is about rationality as efficiency, what Kant called the hypothetical imperative[13] and what Habermas called instrumental rationality.[14]

Collingwood was also correct in pointing out that Sense II must be distinguished from Sense III[15] – the latter belongs to theoretical discourse, what may be called the explanatory context. In that context, we have found Mackie's understanding of causal factors in terms of INUS conditions to be appropriate. However, Sense II is not interested *per se* in INUS conditions, or in looking for all the other necessary conditions which may be jointly sufficient for the effect to occur; it simply assumes that they exist. Rather, it is interested *per se* in identifying as "cause" a factor the manipulation of which would lead to the desired outcome. This would explain why the medical community was finally only convinced that *H. pylori* is "the cause" of peptic ulcers when an antibiotic was convincingly shown to have made a difference to lowering significantly the re-occurrence of the disease through the eradication of the bacterium. We shall see in the next section that this sense of cause is embedded in the concept of Science as Interventionist Science (which necessarily goes beyond mere observation of phenomena), and is deeply implicated in the meaning of the notion of an experiment.

Interventionist Science and Experiment

"Experiment". What does the term mean? According to the *Cambridge English Dictionary*, in its most general sense, it is

> A test done in order to learn something or to discover if something works or is true

A definition with scientific procedure in mind is more focused. An experiment is the testing of a hypothesis. There are two main variables in an experiment, the independent and dependent. The independent variable is the one which when controlled or changed is used to test its effects on the dependent variable.

Scientific procedure/method is said to consist of several steps.

1.The scientific team starts off making observations in the domain of its interest.
2. Based on such observations, it formulates a hypothesis.[16]

[12] For a detailed exploration in genetics of the relationship between the discoveries of basic/theoretical sciences and the technologies generated by them, see Lee 2005. In another domain of science, researchers are busy the world over, today, trying to apply Quantum Entanglement to computer technology.
[13] See Johnson 2016.
[14] See Wedgwood 2011.
[15] Collingwood 1938, 97-8 writes that in this sense, "a cause is necessary (a) in its existence, as existing whether or no human beings want it to exist (b) in its operation, as producing its effects no matter what else exists or does not exist… The cause leads to its effect by itself, or 'unconditionally'; 'in other words the relation between cause and effect is one-one relation…".
[16] The history of science shows maverick ways by which a scientist arrives at a hypothesis. Kekulé (the famous chemist) in 1890 told the German Chemical Society that his 1865 hypothesis about the structure of benzene came from a day-dream, of a

3. It designs an experiment to test the hypothesis.
4. It carries out the experiment.
5. It evaluates the results of the experiment: does the experiment falsify the hypothesis or does it confirm it?[17]

This paper proposes the following definition which is in keeping with the standard account presented above: an experiment is "a deliberate intervention to bring about a certain outcome in order to test a hypothesis". It goes on to show that both domains of MM, CM and (analytic) Epidemiology, carry out experiments as understood in the sense just formulated, as MM is Interventionist Science and Interventionist Science necessarily carries out experiments to test hypotheses.

Experiment in CM

Let us return to the Marshall and Warren discovery of the causal link between *H. Pylori* and peptic ulcer. In his Nobel Presentation Lecture of 2005, Marshall cited two experiments: the first has already been set out earlier; the second will now be presented. Marshall revealed in that Lecture that he swallowed a sample culture of *H. Pylori* and promptly got gastritis.

In an ideal world both kinds of experiments ought to be conducted for the purpose of establishing a causal relationship in the strongest possible sense between the independent and the dependent variables. Let us call one the "disease-generating experiment" (Type I) and the other the "disease-eliminating experiment" (Type II). In reality, Type I is not normally performed because it appears unethical to do so – to expose healthy individuals to a disease-generating condition deliberately to see if they would succumb (and in what proportion to determine Relative Risk) to the disease compared to the individuals in the control arm (who were not thus exposed). On grounds of ethics, we voluntarily foreclose a powerful methodological tool for establishing causal relationships. Sometimes, an exceptionally brave scientist offers himself as such a guinea pig; Marshall did just that. However, it was in one sense a methodologically flawed and futile gesture as his experimental arm consisted of only one participant, that is, himself. No Ethics Committee, in that context, would have allowed him to recruit 100 healthy participants like himself to be randomised to the experimental and control arm of such a type of experiment.[18]

Type II studies are the norm as it is judged ethical to expose ill participants to something which the scientists believe could relieve them from disease or control their illness, but whose effectiveness is as yet not fully established. The aim of the trial is to further test whether the pharmaceutical product is indeed both effective and safe.[19] However, though viewed in a positive ethical light, practical difficulties may remain insuperable in recruiting sufficiently large samples of participants in some contexts. For instance, poor countries lack resources, human, technical and economic to mount such experiments. If a disease is rare, it is difficult to achieve the large samples required.

In the world today, the majority of Type II studies deploying RCTs are conducted by Big Pharma whose aim, however, is primarily to demonstrate to the Food and Drug Administration (in the USA or equivalents in other countries) that the new drug (which is what is often a "me-too" drug) they wish to market performs better than a placebo – see Angell 2004.

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snake seizing its own tail, an ancient symbol known as the *ouroboros*. In the commonly accepted account of scientific methodology, today, the provenance of a hypothesis is immaterial/irrelevant; it is the testing of the hypothesis and assessing the outcome of that testing which are critical.

[17] The Popperian school of scientific methodology upholds falsification as its Gold Standard; others who stick to inductive logic and probability are in favour of confirmation logic.

[18] In the context of the Covid-19 pandemic, this ethical perspective has shifted – the UK launched (21/10/2020) a "challenge trial" of Covid-19 vaccines on young healthy volunteers. This human challenge trial began in early March 2021. This has prompted an ethical discussion, pro and con – see Rohrig and Manheim 2021.

Ethics varies from culture to culture; not all medical scientists have been known to be so scrupulous. An infamous episode occurred during WWII when the Japanese medical scientists of Unit 731 performed abominable physiological and other experiments on civilians and prisoners-of-war. Similar experiments categorically could not take place in the West, at least according to Harris 1995. Harris appears to have overlooked analogous studies carried out in Western countries, such as that on syphilis using black people as experimental subjects in a project beginning in 1932 (when there was no known cure for the disease and ending only in 1972) on the false pretext of giving them medical care – see Nix 2020. James Marion Sims, a southern slaveowner in the 19th century considered to be the father of modern gynaecology built his fame and reputation on subjecting enslaved women to investigation at a time of his life when he knew almost nothing about the subject – see Holland 2018. He did not use any analgesics on the patients during his enormously intrusive examinations because he held the belief in racist biology that Black people simply did not feel pain in the same way white people did. His investigations and interventions created an immense amount of excruciating pain.

[19] Some ethical doubts exist regarding the withholding of even a drug only believed, not proven, to be effective from the control arm. Should the trial show that the experimental arm had benefited from the drug, then participants in the control arm should also be offered the remedy.

Experiment in Epidemiology

This sub-section demonstrates that the concept of experiment as set out above can be found in Epidemiology. Epidemiology since the second half of the last century and in the first two decades of this century is said to differ so much with how it was practised in the second half of the 19th century that some critics perceive them as cheese and chalk.[20] It is, therefore, appropriate from the methodological standpoint to look first at the subject in the 19th century.

Paradoxically, Epidemiology had, then, occupied a more prestigious status, and in that sense, appeared to have scored a brownie point or two for the simple reason that the "magic bullet" of drug treatment didn't take off till as late as the mid-20th century after antibiotics became available as a mass pharmaceutical product following WWII. Up to then, CM could only offer venesection and blood-letting as standard therapeutic measures. What saved many lives came, instead, from Epidemiological interventions rather than pharmaceutical ones.[21]

John Snow's celebrated study of the cholera epidemic in London in 1854 may be analysed from the Interventionist vantage point as follows:

1. Snow made thorough observations of the pattern of the disease in an area of the city which was supplied with water from two different water companies – the Southwark and Vauxhall Company on the one hand and the Lambeth Company on the other.

2. He observed that there was a pump in Broad Street supplied by the first company where the density of residents succumbing to cholera was high; he also noticed that those working at a pub nearby did not succumb as the pub had its own water supply and did not draw water from the Broad Street pump.

3. He found that there were 71 deaths per 10,000 houses in the neighbourhood whose water was supplied by the Southwark and Vauxhall Company but only 5 deaths per 10,000 houses in the neighbourhood whose water was supplied by the Lambeth Company. In other words, the mortality rate in the one was 14 times greater than that in the other.

4. This crucial statistic occurred in spite of the fact that there appeared to be no other significant differences between the people living in the two neighbourhoods, save in respect of their water supply.

(Observations 1-4 above may be said to fall under the domain of Descriptive Epidemiology only)

5. However, Snow did not stop there. Based on above observations, he formulated a hypothesis: the water provided by the Southwark and Vauxhall Company was highly likely to be contaminated.[22]

6. To test this hypothesis, he proposed an intervention: to remove the handle of the pump in Broad Street to prevent people from getting water from it.

7. The intervention was carried out; the pump was disabled.

8. The predicted outcome of the intervention/hypothesis was confirmed/failed to have been falsified – the death rate fell dramatically. The intervention – a Public Health measure – saved many lives.

According to the vantage point of this exploration, the measure would fall under Analytic Epidemiology (5-8 above) as it plainly went beyond mere observation. The deconstruction of Snow's reasoning shows that as the hypothesis led to an intervention, and as an intervention (via the control/elimination factor in a set of INUS conditions) amounts to an experiment in the sense of that concept put forward here, Snow's epidemiological

[20] Epidemiology has been/is a fast-evolving domain of MM. Epidemiology today relies heavily on theoretical modelling, with a set of assumptions (often based on experiment) about mechanisms of transmission, duration of latency, etc. and attempting to predict the likely outcome of different/alternative interventionist scenarios. See Alam *et al*. 2020 as a recent representative example; for the pioneering SIR model, see Kermack and McKendrik 1927. (SIR stands for: Susceptible, Infected, Recovered.) In spite of the obvious differences, this paper emphasises their similarities, that all models (whether earlier or later) rest on the same methodological concept of experiment as Interventionist Science.

[21] For some detailed exploration, see Lee 2012; Wootton 2006; Tansey 1997.

[22] Snow did not know that the contagious agent was the *vibrio cholerae* as that discovery was not made till 1884 by Robert Koch. Ironically, in 1854, an Italian anatomist, Filippo Pacini (1812-1883) had discovered it in autopsies of cholera victims. This error of attribution was not officially rectified till 1965 by the international committee on nomenclature when the bacterium was named *Vibrio cholerae Pacini* 1854 in his honour.

exercise could be said to amount even to a controlled experiment (without randomisation). In what sense is his intervention a controlled experiment and how does it differ from the sort conducted in a drug trial?

(a) Snow could not and did not recruit participants for his experiment, then divide them into two arms (the experimental and the control) in the way drug trials can and do.
(b) His two arms consisted of, by and large, one and the same lot of participants, barring a few who could have moved out of the neighbourhood during the interval between the beginning and the end of his intervention/experiment/trial.
(c) His control group consisted of those who drew on the water provided by the Broad Street pump of whom a significant number fell ill. His experimental group consisted of the same people but this time who could not and did not draw water from the said pump (as it was disabled) and amongst whom the death rate from cholera fell dramatically.
(d) The intervention marked the critical difference between the "control" and the "experimental group".
(e) Snow could have strengthened his scientific arguments by returning the handle to the pump, allowing people to draw water from it again (another intervention) to see if the death rate would climb back up to the level before his first intervention. In other words, he could invoke the analogue of Type I experiment in CM. However, as we have seen, it appeared unethical to do so from the Hippocratic standpoint and Epidemiology as well as trials in CM are absolved from this particular additional burden of proof.
(f) Given the nature of Epidemiological Intervention, Snow could not adhere to the methodological guideline followed by Marshall and Warren in their RCT of dividing the participants into two arms (control and experimental) simultaneously as well as randomising them. In other aspects, Snow's intervention/experiment appears to have followed similar methodological guidelines adhered to in RCTs. RCTs ensure that the two arms are similar in respect of age, gender, diet, lifestyle, and so on; Snow's intervention/experiment/trial satisfies them.
(g) Snow's experiment/intervention was effective even in the absence of any theoretical understanding of the disease-generating agent in question. In this sense, Epidemiology is a distinctive discipline in its own right and not parasitic on other domains of inquiry and study in Medicine. This is not to say, however, as already observed in relation to Collingwood's analysis of cause in Sense II that Epidemiology would not welcome or be incompatible with basic theoretical information,[23] as it necessarily welcomes any source of understanding (from the highly theoretical to the lowly empirical, such as how the people affected by an epidemic see it, how they cope with it in their daily lives) which would enable epidemiologists to formulate a hypothesis and an intervention derived from it which could be tested in the field.

Case-control and Cohort Studies

En passant, we have observed that Epidemiology may be divided into two major domains, descriptive and analytic. The former is carried out in the absence of data about the disease pattern in a population in terms of three aspects: Time, Place and Person. Epidemiologists can plot epidemic curves whose shape gives clues about whether the epidemic is on the upswing, the down slope, or at its terminus. They enable prediction about increase/decrease in the number of cases in the near future. Plotting a spot map (showing where cases are located, which was what Snow did in 1854) give clues about the mode of spread. Person characteristics, such as age, sex, medical status, ethnicity, occupation, use of medication/tobacco/alcohol/other drugs would enable identification of the groups most vulnerable in an outbreak. This last, in particular, could go beyond prediction to intervention, should there be a general political will to do so.[24] It is important to note that Epidemiologists can go beyond Descriptive Epidemiology, like Snow did, to formulate a hypothesis which is testable, which involves an experiment and intervention. In this sense, no firm line can be drawn between mere description and observation on the one hand and hypothesis/experiment/intervention on the other. (Perhaps, in light of this, the very distinction between descriptive and analytical epidemiology can be dispensed with and replaced by laying out a series of steps in thinking which guide their practice and with the findings in practice in turn informing their thinking.)

In the last (20th) century, what may be called Analytic Epidemiology emerged which relies on a comparison group to quantify relationships between exposure and disease as well as to test hypotheses about causal

[23] In the case of SARS-CoV-2, Chinese scientists determined its genome, communicating the results to WHO on 07/01/2020, only a week after the virus had been recognised to appear. The fact that it shares 96% identity with SARS-CoV-1 enables Epidemiologists to devise interventions to control the spread of Covid-19.
[24] In the UK Covid-19 outbreak, Epidemiologists have established that many of those infected of whom some died are front-line health workers as well as workers most exposed to the public such as bus drivers, security guards. Data show that a significant proportion comes from BAME communities (black, Asian/Indian sub-continent and other ethnic minorities, that is, non-white communities in the UK).

relationships. It employs two types of investigation: Case-control Study and Cohort Study.[25] The former is primarily, though not exclusively retrospective and for that reason is said to suffer methodologically from at least one form of bias as cases (those with the disease) and controls (those without) have to rely on memory to provide significant data (such as how many cigarettes were smoked daily in the past). In Case-control Study, investigators are sure of the effect/outcome end of the cause-effect relationship; they are focussed on tracking down the cause end. Cohort Studies are predominantly, though not exclusively, prospective; this paper will be looking at a prospective study only. Such studies are longitudinal: it involves recording over a longish period of time the behaviour of a carefully identified and characterised cohort of participants. The main aim is to see if the predicted outcome (effect) of an already identified disease-generating condition (cause) will actually occur, in contrast to Case-control Study where the focus is the other way round. It is not only time-consuming but also labour-consuming as, in order to be statistically meaningful, it has to involve a very large number of participants who has to be relied on to remain faithful to the study and not to drop out in such large numbers during the period of study as to undermine the integrity of the project.

Let us look at these types of Epidemiological studies via the investigation into the link between smoking and lung cancer, whose findings have been accepted and methodologically acknowledged to put Epidemiology on a proper scientific footing. The work was planned in 1947. This led to the publication in 1950 in the *British Medical Journal* of a paper reporting the results of their research by Austin Bradford Hill (1897-1991) and Richard Doll (1912-2005).[26] This was followed by another paper in the same journal in 1952. Today these two studies are called Case-control Studies. However, its findings, on the whole, did not convince the medical community that the link could be construed as a causal one. It took another type of study – this time, a Cohort Study – involving 40,000 British doctors whose health was monitored (initially) for twenty years, to provide evidence on this score which society and government were unable totally to ignore.[27]

A re-imagination of what Bradford Hill and Doll (1950 and 1952) did, would run as follows:

1. Through a variety of channels in their professional as well as private lives, they came to notice the following: an increase in lung cancer after the end of WWII, that among those who fell prey to the disease were at least a significant number of smokers, that the British government, to help keep up morale of the armed forces during WWII, gifted them with packets of cigarettes. Many soldiers would have grown addicted and after the war ended, in civvy life, they continued to smoke but this time at their own expense.

2. Such observations led them to formulate this hypothesis, namely, that lung cancer could be caused by smoking.

3. How would they test such a hypothesis? First, they arranged to recruit participants for a study. This they did (for their 1952 paper) with the help of eight of the twenty hospitals in London (involved in their 1950 study) as well as hospitals in Bristol, Cambridge, Leeds and Newcastle-upon-Tyne over a two-year period from January, 1950 to February, 1952. The patients admitted, should they be diagnosed with lung cancer, constituted the case group.

4. The same hospitals also selected a random sample of patients not with lung cancer but diagnosed with some other diseases to form the control group. The control group was carefully matched with the case group in terms of age and sex.

5. Both groups, cases and controls, were carefully interviewed about their smoking habits.

6. Doll and Hill identified 1465 case-patients, 1357 men and 108 women, all under 75 years in age.

7. They concluded:

> Of the 1,357 men with carcinoma of the lung 7, or 0.5%, were non-smokers…; of the 108 women here were 40, or 37.0%. The corresponding figures for their paired controls were 61 men (4.5%) and 59 women (54.6%). Of the men with lung carcinoma 25.0% reported that they had been smoking, before the onset of their illness, an average of 25 or more cigarettes a day… The corresponding figure for the male control patients was only 13.4%. For women these proportions were 11.1% for the carcinoma group and 0.9% for the controls. … The validity of these various results is studied, and it is concluded that the association between smoking and

[25] See *Principles of Epidemiology* 2012; Prospective vs Retrospective Studies 2020; Bhopal 2008,15.

[26] Doll's other findings cover asbestos-cancer, radiation-leukaemia, alcohol-cancer links as well as establishing that smoking increases the risk of heart disease.

[27] The results by Doll and Hill were reported in *British Medical Journal* 1954, then 1956. This was followed by Doll and Peto1976 (also in *BMJ*). The last update can be found in *British Journal of Cancer* 2004 by Doll, Peto, *et al.* See also Boyle 2005.

> carcinoma of the lung is real. It is not argued that tobacco smoke contributes to the development of all cases of the disease – a most unlikely event.

In the language of today's Epidemiological discourse, one would present the 1952 findings in terms of Odds Ratio, as shown below:[28]

Daily Cigs (Exposure)	Cases	Controls	Odds of Exposure if Case	Odds of Exposure if Control	Odds Ratio	Scaled Odds Ratio
0	7	61	0.0052	0.0450	0.115	1.00
1-14	565	706	0.4164	0.5203	0.800	6.97
15-24	445	408	0.3279	0.3007	1.091	9.50
25+	340	182	0.2506	0.1341	1.868	16.28
Total	1357	1357	1	1		

Table 1

This table shows that the more cigarettes smoked per day in particular groups, the values of the odds ratio rise suitably, demonstrating that there is a dose-response relationship between the number of cigarettes smoked daily and the strength of the association.

8. The figures of this Case-control Study point to an obvious Intervention: to avoid getting lung cancer, smokers should reduce daily cigarette consumption, best of all to stop smoking altogether. However, politically, no scientist would dare advocate this openly and no government would dare to act upon it given the power of the tobacco lobby, the revenue to the Exchequer from the tobacco tax, the genuine pleasure tobacco-smoking seemed to give to smokers.

To overcome criticisms against their Case-control Study, Doll and Hill towards the end of 1951 began mounting a prospective Cohort Study by obtaining 40,701 (34,494 males and 6207 females) usable responses from British doctors. At around the same time, a similar Cohort Study was conducted by Hammond and Horn of the American Cancer Society; to be followed in the same decade by four other large studies. All these studies produced results which comfortably bear out the findings in the earlier much criticised Case-control Studies. They confirmed the association between smoking and lung cancer as well as revealed that cigarette smoking is also a risk factor for coronary heart disease. The lung cancer death rate was substantially higher in cigarette smokers than pipe or cigar smokers. Very significantly, they showed that as smoking increased so did the association between smoking and lung cancer increase. The 50-year follow-up paper (Doll, Peto, *et al*.), published in 2004, demonstrates that the obverse also holds – quitting smoking reduced the death rate. Men born in 1900-1930 who smoked continuously died roughly 10 years younger than men who never smoked, while stopping at age 60, 50, 40 or 30 years gained respectively about 3, 6, 9 or 10 years more of life.

The prospective Cohort Studies (1954, 1956, 1976, 2004) also imply the same Interventionist Measure, that the sooner smokers quit smoking, the better off they would be.

These findings eventually led countries to ban smoking in the workplace; Ireland was the first in 2004 to do so with a substantial fine for breach of the law. This set the ball rolling with many countries introducing similar laws. Scotland in the UK followed suit in 2006. In other places, such as California, smoking was also banned on beaches and in public parks. The law varies from country to country in the kind of space where smoking is not permitted. In the UK, smoking is not allowed on public transport, inside pubs and restaurants; however, smoking is permitted along the street. The reach of this set of findings is truly far reaching as a public health measure which impacts on every one in society whether smoker or non-smoker.

This series of papers on smoking and lung cancer show that there is a dose-response relationship between the cause and the effect variables, just as the Case-control Study of 1952 has done. This kind of causal relationship instantiates Mill's Method of Concomitant Variation:

> Whatever phenomenon varies in any manner whenever another phenomenon varies in some particular manner, is either a cause or an effect of that phenomenon or is connected with it through some fact of causation. (Mill 1843, Vol.1).

Schematically it can be formulated as follows:

[28] This table is provided by Daniel Oi (Strathclyde University, Physics). Note that it differs from Chandola 2020.

An OR, say, of 1.868 means that individuals who were exposed to 25+ cigarettes daily are 1.868 times more likely to get lung cancer than those not so exposed.

A B C occur together with x y z	x y z occur together with A B C
A± B C results in x± yz	x± yz results in A± B C
Therefore, A and x are causally connected	Therefore, x and A are causally connected

This method, as we have seen, demonstrates that quantitative variations between two factors occurring in a systematic manner may be understood as being causally related.

Covid-19 and Interventionist Measures

On 11 March 2020, WHO declared Covid-19 a pandemic[29]. As of 23 June 2020, it continued apace in Russia, in terms of new cases in Mexico, Pakistan and Bangladesh, and in terms of new deaths in Mexico, Russia, Pakistan and Bangladesh (according to Worldometer Coronavirus). So far (as of end of October 2020), no effective pharmaceutical products – drugs or vaccines[30] – had yet been devised and/or marketed. Medicine, left with non-pharmaceutical measures, relied on Epidemiologic strategies which are informed by understanding and data provided by the two other outbreaks of coronavirus in the first two decades of the 21st century, SARS, originated in China in late 2002/early 2003 and ended by July 2003; and MERS, originating in the Saudi Arabian Peninsula in 2012. In terms of fatality, MERS leads with 3-4 out of 10, SARS, with 1in 10, and Covid-19 with an estimated value of 0.26% (which takes into account both symptomatic and asymptomatic cases, according to the US CDCP).

From these data, Epidemiologists hypothesise in the case of the current pandemic that there is animal-to-human transmission, human-to-human transmission, transmission occurs during close contact with those already infected, with transmission taking place primarily via aerosols when those infected sneeze or cough or indeed even talk. Low-level preventive measures include advising people to wash the hands regularly with soap and water/clean hands with sanitiser; to sneeze or cough into one's elbow; regularly to clean surfaces with disinfectant; to wear gloves, masks and even goggles (if the context demands), to shield exposed members of staff who have to serve members of the public in shops behind protective barriers; to keep social/physical distancing of 1 meter or 2 meters depending on the country and circumstance.

However, such low-level preventive measures turned out to be not enough in many instances. More highly organised preventive measures were called for, the deliberate interventions at the level of government and health agencies. WHO had been urging governments since early March 2020 to "test, test, test". This, however, should be taken as short-hand for a comprehensive set of measures covering test, track, trace and isolate, as testing on its own, not followed up makes no sense. (Let us call this **The Testing Intervention**, for short). Testing will show if the person has got the virus or not. If the result is positive, then the person is required to self-isolate for 7-14 days while monitoring the development of the virus to see if mild, serious or no symptoms will be manifested. Epidemiologists need to track the movement of the virus through the general population, so that one can understand the rate of infection (the "R" number) as well as to find out how many people have developed antibodies to the virus. In order to slow the spread of the virus, tracing is essential – if someone tests positive, then one needs to work out where they have been and whom they might have come into contact with. These measures must be acted upon swiftly and efficiently. If test results take several days to be known, this would give more than ample opportunity for the virus to spread through the population, at an exponential rate (if R is greater

[29] WHO earlier in January 2020 had declared a "PHEIC", the official-agreed technical term to refer to what in common language is called "pandemic"; however, countries generally (outside the Pacific Area) appeared to ignore that "PHEIC" equals "Pandemic".

[30] On 16/06/2020, the Nuffield Department of Medicine, Oxford University announced the outcome of an RCT, showing that dexamethasone could reduce death in critically ill patients by roughly a third for those on ventilators and a fifth on oxygen alone. Another drug, remdesivir (used in the Ebola outbreak, and found promising in laboratory and animal studies in SARS-CoV-1 and MERS-CoV) was tested in an RCT in China; *The Lancet* on 29/04/2020 reported it has been found to shorten the illness by four days (15 to 11) in severe hospitalised cases on supplemental oxygen. However, these drugs are no "magic bullet"; they work only for the critically ill. They cannot prevent mild cases from becoming severe ones; nor are they of help to survivors with many health (Long Covid) problems.

Globally, there were over 200 vaccines being developed (by October 2020) which differed in their design methods some having already reached Phase 3 of testing for their efficacity and safety. The period of efficacity for each was not known initially. Since October 2020, when vaccines had started to roll out under Phase 4, data have become available. See Felter June 2021 for an update about the concerted efforts worldwide to produce vaccines either through the efforts of governments, private firms, charities and organisations such as WHO which have turned out to be an unprecedented achievement in the history of vaccine development – what in the past took up to 12 or 13 years to develop and manufacture was made available within a year. See also Farrar 2021.

than 1). Governments which have been efficient and quick off the mark have been very successful in controlling and sometimes as good as even eliminating the virus from their countries.[31]

Countries have/had also put in place what may be called **The Lockdown Intervention** which has taken place in whole counties/provinces/counties. Data show that the sooner Lockdown is effected, the sooner the epidemic curve would start to decline, and the less cases of infection would arise with less fatality amongst those affected.[32] Strictly speaking, it is correct to say that Epidemiology cannot conduct Controlled Trials (never mind Randomised ones); it remains true to say, nevertheless, that "controls" are available for study, observation and analysis. Different countries make different political decisions in spite of the fact that they all claim to be following "the Science". "The Science" may tell them that the right measure to adopt is to lockdown, but some governments may choose to ignore "the Science" for political reasons, until the pandemic has advanced and they are 'staring into the abyss" of ever-increasing infection rates and ever-increasing mortality rates. The UK government is one such which springs immediately to mind – see Farrar 2021. Downing Street did not announce a lockdown till 23 March 2020, although 'the Science" had all the data available to it from China, South Korea, Singapore, Italy and Spain.[33] As a result, the UK (as at 24/06/2020), according to Worldometer had the honour of being the fifth highest in the world of Total Case, the highest in Europe of Total Deaths, very charitably the third highest in the world of Death 1m/pop (after San Merino at 1,238 and Andorra at 673). It is perhaps appropriate to compare the UK and Germany, two advanced economies and liberal democracies in Western Europe,[34] in spite of the fact that the pandemic is a fast-moving phenomenon – comparing Tables 2.1 and 2.2 makes this point. Germany put in place Lockdown (beginning 13/03/2020 with school closures)[35] backed up by an efficient system of test-track-trace-isolate and other supportive measures. The difference in the data – see Table 2.1 – is stark and requires no further comment.

	Worldometer (as of 24/06/2020)			Johns Hopkins University Coronavirus Resource Centre (26/06/2020)			
Country	Total Cases	Total Deaths	Death 1m/pop	Confirmed	Deaths	Case-fatality Deaths per 100 confirmed cases[a]	Deaths 100K pop[b]
UK	306,210	42,927	632	309,456	43,314	14% (5.6%)	65.14 (66.55)
Germany	193,281	9,003	107	193,371	8,940	4.6% (2.5%)	10.78 (11.95)
China	83,430	4,634	3	84, 901	4,641	5.5% (5.2%)	0.33 (0.34)
Sweden	60,837	5161	511	63,890	5,230	8.2% (5.5%)	51.36 (58.22)
Denmark	12,615	603	104	12,836	603	4.7% (1.8%)	10.40 (11.90)

Table 2.1

[a] & [b]: Figures within round brackets as of 22/10/2020.

[31] This does not mean that there cannot be a second wave. South Korea is often cited as a highly successful case of containing/controlling/eliminating the virus through its thorough-going Testing Intervention in its population of 51.8m – those tested received their results within 14 hours, its use of monitoring techniques, including CCTV camera records and credit card transactions to alert members of the public where the infected had been before they tested positive. In May 2020, a new cluster appeared, but was quelled using similar techniques. Hong Kong, Singapore and Germany have/had also put in place an efficient system of Intervention Testing, with successful results.

[32] The report of the China-WHO Joint Investigation Report on COVID-19 (published on 29 February 2020) concludes that the interventions implemented in China do work but fears that: "Much of the global community is not yet ready, in mindset and materially, to implement the measures that have been employed to contain COVI-19 in China. These are the only measures that are currently proven to interrupt or minimize transmission chains in humans. Fundamental to these measures is extremely proactive surveillance to immediately detect cases, very rapid diagnosis and immediate case isolation, rigorous tracking and quarantine of close contacts, and an exceptionally high degree of population understanding and acceptance of these measures."

See also Coronavirus Resource Center, Johns Hopkins University and Medicine: Hubei Timeline. URL = https:/ /coronavirus.jhu.edu/data/hubei-timeline . Retrieved 30/08/2021.

[33] However, the Health Secretary, Matt Hancock testified before the joint hearing of the Select Committee of Science and Technology as well as the Health and Social Care Select Committee of the UK Parliament on 10/06/2021 in which he declared that he at all times listened to "the Science". See *The Guardian* 27/05/2021: 1-9; BBC 12/06/2021. Fact-checking Matt Hancock's Covid claims – URL = https://www.bbc.co.uk/news/57427777. Retrieved 30/08/2021.

[34] Population-wise, Germany has roughly 12 million more.

[35] The Chancellor initially did not appreciate that the virus could cause such havoc, but soon changed her mind.

As of 10/08/2020: the world's three leading countries	Worldometer	Johns Hopkins Coronavirus Research Centre [a]
	Numbers Infected	Death Figures
USA	25.95% 5,208,742	160,047 (221,176)
Brazil	15.11% 3,035, 582	101,049 (155,403)
India	11.08% 2,226,229	46,091 (115,914)

Table 2.2

[a]: Figures within round brackets ss of 22/10/2020

Excess Mortality (Ourworldindata.org): March/April-to end of July 2020							
USA	UK	Italy	Spain	France	Germany	Sweden	Denmark
175,700	63,919	43,945	43,261	29,073	9.303	5,332	447

Table 3

Worldometer (as of 30/08/2021)			
Country	Total Cases	Total Deaths	Death 1M/pop
USA	39,665,883	654,689	1,965
India	32,745,457	438,411	314
Brazil	20,741,815	579,330	2,703
UK	6,731,423	132,437	1,939
Sweden	1,123,413	14,644	1,440
Denmark	344,850	2,580	444
China	98,842	4,636	3

Table 4.1

Johns Hopkins University Coronavirus Resource Centre (30/08/2021)			
Country	Total Cases	Total Deaths	Deaths/100K population
USA	38,796,746	636,531	194.23
India	32,737,939	438,210	32.07
Brazil	20,741,815	579,308	274.49
UK	6,562,904	132,760	198.64
Sweden	1,123,413	14,685	142.77
Denmark	345,421	2,582	44.38
China	107,012	4,848	0.35

Table 4.2

"The Science" in the UK has been led, on the whole, by a committee called SAGE (Scientific Advisory Group in Emergencies) who initially advised the government not to lockdown. British scientists were also initially led to believe that two-thirds of cases were undetected whereas they later realised this was not so; the data suggested the number was nearer 90 percent. Official statistics show that only 273 of 18.1 million people entering Britain by air in the three months leading to Lockdown were quarantined, the remainder was simply given a leaflet about symptoms of the infection and what to do should they believe they got the disease. Scientists eventually found that about 34 percent of UK's cases came from Spain, 29 from France, 14 from Italy and 23 from the rest of the world, with less than 0.1 percent from China. They also have established that at least 30 percent (but could be nearer 50) of UK deaths was associated with nursing homes.

Epidemiologists in the paper "Estimating the effects of non-pharmaceutical interventions on COVID-19 in Europe" (*Nature*, 08/06/2020) have claimed that "major non-pharmaceutical interventions and lockdown in particular have had a large effect on reducing transmission"; if Lockdown had not occurred on 23/03/2020 in the UK, then 470,000 lives would have been lost by 04/05/2020.[36] A member of SAGE had claimed that Lockdown earlier could have saved more lives (BBC/07/06/2020). Professor Neil Ferguson of Imperial College and member of SAGE told a UK parliamentary committee on 10/06/2020 that locking down a week earlier than 23/03/2020 would have reduced the death toll by "at least half".[37]

Philosophers are only too keen to warn people in general and historians in particular about the inherent difficulty if not impossibility of testing counterfactual propositions. All the same, the counterfactual proposition uttered by Ferguson is not devoid of empirical backing, given the data underpinning the expert understanding of

[36] See https://uk.reuters.com/article/us-health-coronavirus-lockdowns/lockdowns-saved-many-lives-and-easing-them-is-risky-say-scientists-idUKKBN23F1G3.

[37] See UK scientist: Week earlier lockdown could have halved deaths. In *MedicalXpress*, 10/06/2020.

the R number,[38] the method used by the virus in its propagation (by aerosols, for instance), its genomic structure and so forth which a model can incorporate; its projected scenarios were not simply plucked out of thin air, although it remains absolutely correct to note that all models have built-in assumptions which are not incontestable and some of which may even be wholly unjustified and wrong.

Another relevant country to look at is Sweden. Sweden for political/cultural reasons did not lockdown, preferring to pursue herd-immunity,[39] although other European countries did. Denmark, a fellow Scandinavian country, was one of the first in Europe to lockdown, on 11/03/2020. Table 2.1 shows the difference in outcome, confirmed by Table 3. Although Sweden's population is 10 million and that of Denmark is 6 million, other differences between them would not be overwhelmingly large, as their populations are predominantly Nordic, they are both advanced economies with excellent social and health infra-structures. Furthermore, one must bear in mind that Sweden is ten times bigger in size than Denmark, although just under twice as large in population as its more southerly counterpart. However, the stark difference in outcome between them stands out. Although it is acknowledged that no two countries can be said to be similar except only in one respect, it remains reasonable and plausible to conclude that the difference in outcome in this instance could be tracked to the difference between Lockdown and No-lockdown, or at least to the difference between pursuing the policy of herd immunity on the one hand and that of controlling the spread of the virus through a package of strategies which included testing and lockdown on the other.

The key thesis put forward and defended by this contribution is that Epidemiology is capable of formulating hypothesis/hypotheses from which may be derived Intervention(s), which in turn could be tested if not directly via a controlled experiment but via indirect means such as comparing cases where the Intervention occurred and those where it did not occur. The Intervention implies: If the authorities do X (such as Lockdown), then the number of cases and of mortality will be less than in those (comparable) cases where the authorities fail to do X. If the predicted differences in the figures for the two types of cases are y, then the Intervention is verified/not falsified; if the figures are z (the opposite of y), then the Intervention is falsified. The comparison could be guided by using criteria such as Number of deaths from Covid-19 per 100K or 1 million in the population, or excess deaths associated with covid-19 in 2020. The use of the latter criterion also shows up the stark difference between Sweden and Denmark, which lends weight to the conclusion that Sweden had fared badly because of the policy it pursued while Denmark had fared much better given the policy it pursued – see Islam et al. 2021.

One very important point to end on – suppose that Lockdown does not work, what does that prove? It proves that Epidemiology has formulated a particular hypothesis, which when subjected to testing, turns out to be false. It does not prove that Epidemiology as a scientific discipline is incapable of formulating hypotheses which when subjected to testing will always fail; nor does it prove that Epidemiology is a discipline which inherently tries to avoid falsification when its interventions fail in their predicted outcomes.

Conclusion

1. The goal of MM is to cure diseases, and/or to prevent diseases from occurring, or reduce the rate of disease-occurrence.

2. According to medical consensus today, diseases rarely conform to the one cause-one effect model; rather, causation is multifactorial with complex interplay between the numerous variables/risk factors (Mackie's INUS conditions).

3. Medical scientists select one of these INUS conditions as the cause using the criterion of controllability, according to Collingwood's Sense II of the concept of cause. This means: pick on that condition which can be used to generate an Intervention.

4. An Intervention amounts to an experiment: do x and y will occur; failure to do x leads to non-occurrence of y/the occurrence of z (the opposite of y).

5. An Intervention implies a hypothesis, which together with statements about initial conditions entail statement about an outcome which is testable.

6. MM is Interventionist Science whether the intervention is made in CM as RCTs or in Epidemiology as non-pharmaceutical strategies (Testing/Type A and/or Lockdown/Type B Interventions).

[38] The average number an infected person infects others. If R is more than 1, this would be worrying; if it is less than 1, then the epidemic/pandemic is on the wane.
[39] It did adopt some softer measures such as shielding the vulnerable.

7. Not all MM Interventions can in practice and for ethical reasons be conducted as RCTs using randomisation to assign participants to the experimental or the control arm of the study. Only some limited cases can be. RCTs can show that some treatments/drugs are more effective than others just as Epidemiology can show that some non-pharmaceutical measures are more effective than others. The Covid-19 Epidemiological Interventions have been shown to have saved many lives.

8. In principle, both CM and Epidemiology could engage in Type l experiments/or their analogues to reinforce their respective causal claims; however, both may decline to do so on ethical grounds. They invoke only Type ll experiments and their analogues.

9. The test of the pudding is in the eating. If the Intervention works, the outcome is as expected, then it bears out a causal association between exposure to the risk factor and the outcome. With Covid-19, the Testing/Type A and the Lockdown/Type B Interventions have reduced the spread of infection.

It is no part of the logic of Intervention/Experiment to guarantee its own success; on the contrary, it is carried out with the precise aim of ascertaining its outcome, which may be a failure. However, failure does not mean that the Intervention/Experiment as well the hypothesis from which it is derived are not scientific. Following Popperian methodology, to be scientific is simply to subject the hypothesis to testing via an Experiment/Intervention which can yield either success or failure.

10. The framework provided by the concept of MM as Interventionist Science enables one to argue that Epidemiology should not occupy a position below that of RCTs in PE – they should be at the same level, each making its own contributions to the goal of protecting people from suffering/death brought on by disease. RCTs typically aim to provide pharmaceutical products to cure disease-victims or to prevent disease-infection; Epidemiologic Interventions typically aim to prevent large swathes of the population from the disease through non-pharmaceutical measures. Both are forms of Interventionist Science/Medicine, each with its own distinctive methodological procedures. One should not judge "the goodness" of one kind of Interventionist Medicine using the procedures for judging "the goodness" of another kind of Interventionist Medicine – to do so would be just as silly and absurd as to judge a dog show by the standard of "goodness" relevant to a cat show and *vice versa*. A cat is just not a sub-standard dog, as it is patently not a dog. PE as it stands appears, unfortunately, to embody this kind of irrelevance if not absurdity.

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