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The History of Vaccination

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Chapter 10
Serendipity, Luck and Collective Responsibility in Medical Innovation—The History of Vaccination

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Abstract Martin Sand and Luca Chiapperino find in the concept of serendipity a versatile umbrella term to reassess their previous work on moral luck and collective responsibility. Moral luck supposedly occurs when someone receives praise or blame for things beyond control. Given the ubiquity of luck, this seems to be a seriously disquieting aspect of ordinary morality. The rewards and recognition for serendipitous discoveries fall into exactly this category. That is: more than the intentions, actions, and characters of scientists matters for discoveries to obtain, just as in cases of moral luck something beyond morality affects our moral judgments. Even if a theoretical way of resolving the conceptual ambiguities that underlie this debate were found, there remain practical questions of how to perform stratification in science and innovation in ways that both hinge on, and yet refrain from, considerations of desert and achievement. With the example of Edward Jenner's luck- and serendipity-infused discovery of vaccination, the authors attempt to better understand the intricate value trade-offs that underlie stratification policies in science, which have to be constantly re-negotiated to maintain their legitimacy. Thereby, Sand and Ciapperino aim to take a bold step towards understanding the ethics of serendipity.

In this chapter, we consider the history of vaccination and discuss its relation to the notions of serendipity and luck. Edward Jenner is usually credited with the discovery of the basic mechanism of vaccination that led to the eradication of smallpox: However, when dissecting this case in more detail, we will find that luck was involved in various shapes and forms throughout this process. Given the conceptual proximity between luck and serendipity, the discovery of vaccination has also been considered serendipitous (Roberts 1989). It has been suggested, that is, that Jenner was made

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aware of the immunizing effect of cowpox by a milkmaid during a rather accidental encounter.

This account, which identifies luck in the antecedent conditions of the finding—conditions which he did not control—has been challenged by historians. Serendipity is often understood as "finding the unsought" (van Andel 1994) or "looking for something and finding another" (Gillies 2015). In light of these notions, Jenner's exposure to rumors in the dairies makes vaccination indeed seem like an unsought finding, but much of this assessment hinges on information that historians are lacking, as we will show. In contrast to this traditional account, we will suggest it is better not to identify serendipity as appertaining to Edward Jenner's realizing that vaccination might be an effective medical procedure (after receiving the hint), but rather to appeal instead to a notion of serendipity as an emergent property of the collective effort that ultimately made vaccination a global success (Copeland 2018): That is, vaccination could become a global standard for disease prevention only through advancements in microbiology and sterilization techniques (to which Ignaz Semmelweis (Gillies 2005) and later Joseph Lister made major contributions in the second half of the nineteenth century (Lister 1867), and that formed the basis of Pasteur's work that followed suit), as well as the global effort of the World Health Organization (WHO). Jenner's early experiment is only one building block in the monument that is today's common practice of vaccination. Serendipity is, thus, present as an emergent property of this process rather than being confined to the "moment of discovery".

Describing these events with a slightly different terminology, one might suggest that *luck* has influenced the development of vaccination—luck provided the circumstances and contributed to the results that made vaccination a global success story.[1] Surely, luck is not always related to discovery: Luck in gambling is not serendipitous. But all serendipitous discoveries contain luck: If something unsought is found, it has not been pursued and something that has not been pursued was not (intentionally) under control. Luck is oftentimes understood to be a significant event beyond someone's control.[2] There is clearly an affinity between serendipity and luck (Sand and Copeland 2020).

Consider that at the moment of his first vaccination experiment—the first documented vaccination experiment with systematic intent[3]—Edward Jenner could by no

[1] Paul Thagard seems to use both terms interchangeably. He puts "questioning" in the centre of his psychological model of discovery and suggests that serendipity can lead to surprise and thus further questioning. Thus, serendipity is not a combination of wisdom and chance, but comes entirely from outside the agent (Thagard, 2011). In this way, it could be replaced with the concept of luck.

[2] Luck is conceptually at least as fuzzy as serendipity (Hales 2020). Clearly, many things that are significant and beyond one's control are not things we consider to be luck: The fact that the sun rises every day ensures survival and is beyond our control, but not really lucky. Hence, philosophers wrestle with adding qualifying conditions such as likelihood to exclude such cases from the extension of the concept. However, even this does not seem to make the concept of luck any clearer: The chances for surviving a round of Russian roulette are pretty high, yet, most of us would consider themselves lucky when surviving.

[3] It is important to underscore that previous vaccination experiments have been undertaken without medical or systematic intent by Benjamin Jesty (Pead 2003, 2006). Unlike Jenner, Jesty indeed undertook these "experiments" on his family members.

means be certain that the vaccine had induced immunity in the eight-year-old James Phipps when he infected him with smallpox. In other words, he put the boy at risk of dying. Had that happened, current judgments about his service to medicine would be very different from what they actually are (Sand et al. 2019). Jenner would have probably vanished from the annals of medical history. In his own reflections on the experiment, he expresses "anxiety" and uncertainty: He was not entirely confident in the success of the procedure and was aware of the accompanied risks (Jenner 1801). Luckily, the procedure worked and James Phipps survived.[4]

But, vaccination as a medical practice continued to face resistance. The procedure had several shortcomings based on misunderstandings that Jenner himself induced, and it took a long time to convince the general public of its merits (we will return to this later on). Only through fervent advocacy by influential aristocrats, the invention of modern sterilization methods and the global effort of the WHO, could vaccination lead to the global eradication of smallpox. These too are instances of luck—matters beyond his control—that nonetheless have had some striking effects on our (moral) assessment of Jenner and his perceived role in the vaccination revolution: He is often mentioned as the most important agent towards this unique medical innovation. In this manner, we will read the case as one of moral luck and take this as a backdrop to problematize the usual means of stratification in science and policies of publicly attributing merit and commemorating individual achievements. That is, we argue that Jenner is elevated to the Pantheon of medical heroes for vaccination's global success in spite of the contributions of numerous other actors. In summary, we suggest that Jenner can count himself lucky in two distinct ways: First, he undertook an experiment that could have failed dramatically, but succeeded instead. Second, without a number of contingent factors (including additional medical progress and efforts by other actors) melding in the right way, his finding could not have become the global success for which he is hailed. Both of these were beyond his control, which is in our view a constitutive condition for luck (see footnote 2).[5] We will start by sketching the forebear of vaccination and the historical context of Jenner's first vaccination experiment.

Vaccination, Serendipity and Moral Luck

Roughly speaking, vaccination is a medical practice, whereby one receives an injection of a mild form of a certain disease in order to activate the body's immune-system to produce antibodies to later resist stronger versions of the same disease or diseases of the same family. In the eighteenth century, the working mechanism behind these

[4] Jenner might not have been aware, despite acknowledging the risks involved, that this was in fact a matter of luck. To him, the procedure—and its eventual success—might have been the logical and necessary consequence of the conviction that his hypothesis was right. Why the hypothesis was right, though, he could not have fully understood at the time. Clearly, how strongly one is convinced of a hypothesis and how far one decides to go to prove it, is not only a matter of epistemology, but also of research integrity. We thank Samantha Copeland for bringing this point to our attention.

[5] We believe that there has been agential contribution to this process, which might have been necessary, but was insufficient for the success of vaccination. In a deterministic universe, in contrast to this view, all causality is necessary and sufficient.

facts—the role of the immune systems and antibodies—were still unknown (Helmstädter 2008). What existed, then, was a pre-form of vaccination called "variolation", which was already practiced in ancient China and the Middle East, according to several historical accounts, and reached England in the early eighteenth century (Boylston 2012, 2013; Williams 2010): Lady Montague brought the practice from Turkey to London and applied it to her kids. Robert Sutton from Suffolk in England was a doctor who practiced variolation systematically and also applied it to his kids (Gross and Sepkowitz 1998). The Suttonian method of variolation was widely known and a source of great fortune for the Suttons (Bazin 2000). Naturally, when Jenner's method got traction, the Suttons had the strongest reservation against vaccination.

When he was just a child, Jenner himself underwent the Suttonian treatment. Variolation works by injecting a mild form of smallpox into the upper layer of the skin. The skin cells will send all necessary information about the bacteria to the immune system, which immediately starts developing anti-bodies. By the time the smallpox reaches the bloodstream, the body has already developed all necessary defences and can easily fight off the main attack. The problem with variolation is that if it is practiced wrongly and smallpox is infused too deep into the skin, there is the risk that the patient suffers a full-blown smallpox infection, which at the time was highly lethal and left many people disfigured (Baxby 1999; Williams 2010). Furthermore, by inoculating people with the smallpox, you immunize them against the disease, but while they are infected, they remain infectious to others and could become a source of bigger outbreaks.[6]

Therefore, while variolation helped to immunize some people it also meant procreating the disease. Something better was required. Against this historical backdrop, Edward Jenner was the first to systematically investigate and describe a different method, which he called "variolæ vaccinæ". The treatise *An Inquiry into the Causes and Effects of the Variolæ Vaccinæ*, in which he suggests that cowpox protects from contracting smallpox was first privately published in 1798 and in a revised version by Ashley & Brewer in 1802 (Jenner 1802a). In Jenner's time, the distinction between medical science and medical practice was much less clear (Jewson 1976). In the practice of what Jewson calls—"bedside medicine"—statistical methods and systematic experimentation were not yet fully developed. Medical knowledge was primarily gained on the basis of patients' accounts of a disease experience (Jewson 1976). Despite this, the original *Inquiry*, which Jenner recommended to the Royal Society for publication in 1798, was even in his time considered to be based on too much circumstantial knowledge: Sir Joseph Banks, president of the Royal Society

[6] In particular, the latter of these two points has been disputed by Peter Razzell (1965). Razzell suggests that the contagiousness of the person diminishes with the severity of infection. Since inoculated patients sustained only mild forms of disease, they remained allegedly non-infectious. Furthermore, he claims that initial vaccination experiments were misinterpreted: Jenner mistakenly thought that he had conferred cowpox on his patients, while it was in reality a variation of smallpox. Rezzal's paper has been controversially discussed and published with an editorial note and comment. Our account is largely based on Gareth William's research (Williams 2010). It is noteworthy that before proper methods of sterilisation the method of inoculation suffered from the same issues of transferring other forms of bacteria from human to human.

in London, rejected the original treatise because Jenner's account relied on too few observed cases (Baron 2014; Bazin 2000, p. 39).

While the *Inquiry* contains all essential *ingredients* to kick off a medical revolution, it is often considered a somewhat careless and prematurely published study (Baxby 1999; Beale and Beale 2005). It contained a number of flaws that haunt the vaccination debate until today: First, in the original version, Jenner acknowledged only in passing that there are different types of ulcers to be found on the utters of cows, some which he considered "spurious cowpox" and some "true cowpox". The "spurious cowpox" had a different virological nature and could be harmful to humans. It did not produce the sought immunity against smallpox. Hence, distinguishing the two was of utmost importance, which Jenner failed to do with the required precision. Second, Jenner assumed that vaccination would protect people for the rest of their lives from contracting smallpox, which is not true. The effect wears off after some time and has to be refreshed. He drew a premature conclusion from his early studies (Baxby 1999, p. 305).

Third, he asserted that one could perfectly well inoculate patients with bacteria from other patients, who had been infected with cowpox, instead of using the pox material directly from cows. Given the lack of proper aseptic techniques at the time, this meant that the procedure likely transmitted other infectious diseases like syphilis from human to human (Baxby 1999), a flaw that appertained equally to the practice of variolation. A serious side-effect of the procedure until at least the beginning of the twentieth century was, hence, that a significant number of people developed bacterial infections through non-sterile vaccination equipment. This—although not directly caused by vaccination—fuelled vaccination opposition and gave rise to prejudices that did not easily vanish even after proper hygiene techniques were developed.

Fourth, Jenner's idea of inoculating humans with matter coming from the bodies of humble dairymaids (like Sarah Nelmes, whose case was reported in his *Inquiry*) or even the udder of cows was in many ways subversive. On the one hand, it challenged established social orders by rendering the bodies of the bucolic and ignorant members of eighteenth century British society essential to the well-being of their social superiors (Fulford and Lee 2000). The owners of the lands and cattle now depended on the bodies of the women and men whose labour they condescended to. On the other hand, Jenner's technique affirmed also a fundamental unity of the living, which was problematic for the medical establishment of that time. Cattle and humans did not only display similar diseases, in Jenner's view, but these could actually travel from one to the other. This is the fundamental reason why Jenner's ideas were received with mockery and fantasies of transmogrification of humans into sick beasts on the side of the general public (Stern and Markel 2005), and as "Jacobin innovation" on the side of the Royal Society (Fulford and Lee 2000, p. 142).

In this historical context, and given the outspoken opposition of the Suttons and other sceptics of Jenner's work who made a living from variolating, and given the fragility of the case for vaccination (Baxby notes that "Jenner's actual experimental evidence as presented in the *Inquiry* was not great and was not to be significantly increased in his later monographs" [Baxby 1999, p. 306]), euphoria for the new preventative treatment could have easily ebbed away. Luckily, Jenner had a number

of influential, aristocratic proponents, who carried the fire of vaccination on (Baron 2014), and future medical progress provided a remedy for some of the early flaws of the method. This shall be discussed in more detail now from the perspective of serendipity.

Vaccination and Serendipity as an Emergent Property

Let's turn to the question of serendipity. The term "serendipity" was coined by Horace Walpole, who wrote to Horace Mann: "I once read a silly fairy tale, called *The three Princes of Serendip*: as their Highnesses travelled, they were always making discoveries, by accidents *and* sagacity, of things which *they were not in quest of*". (Merton 2004, p. 2; own emphasis) The statement suggests two necessary conditions for a discovery to be considered serendipitous. The first is the presence of wisdom or sagacity along with the accident: A person or collective has to have the right mindset or the "keen eye" to recognize the value of what they stumbled over (Macfarlane 1984). The words attributed to Louis Pasteur, who claimed that "chance only favors the prepared mind", resonate with this (Bennett and Chung 2001). The second condition is the role of accident: That this "stumbling over something" is indeed accidental—whatever is found has not been sought and comes as a surprise (van Andel 1994).

The traditional serendipity perspective applied to the case is that Jenner was made aware of the potential of vaccination by a milkmaid, who contracted cowpox and allegedly never contracted smallpox despite nursing smallpox patients (Roberts 1989). In an article by Edward Compere from 1957 in the *Journal of the American Medical Association*, we find this traditional account of the so-called "milkmaid myth", which is adopted by Royston Roberts and many others (Barquet and Domingo 1997; Compere 1957b). Roberts relies in his account entirely on Compere's, as he cites the following passage (p. 20):

> Jenner did not discover his vaccine as a result of long and arduous work in a laboratory. At the age of 19 years he was told by a former milkmaid that she could never have smallpox because she had had cowpox. Jenner recalled this statement when later, as a physician, he realized the futility of trying to treat the disease. […] This was true serendipity. The fact that cowpox gave immunity to smallpox came to him without effort on his part. He had the good judgement to recognize its value and to make use of it. (Compere 1957a)

In his analysis, Compere underscores that both conditions are met and stresses particularly the first: He emphasizes that Jenner had made no effort to find such insight. He bumped by accident into the milkmaid, who gave him the clue. This account of the events has been hawked by Jenner's biographer John Baron (Baron 2014). Current historians of medicine, most outspokenly Arthur Boylston, contest it (Boylston 2018). It is more likely that Jenner learned of the possible immunizing effects of cowpox from Andrew Fewster during his years as a student physician in 1768. Jenner himself suggested in 1801 that his work on cowpox "commenced upwards of twenty-five years ago". (Jenner 1801) He himself confirmed in these publicized reflections that the milkmaids' immunity was "known among the dairies" at the time: "On inquiry, it appeared that it had been known among the dairies time immemorial,

and that a vague opinion prevailed that it was a preventive of the Small Pox". (Boylston 2018; Jenner 1801, p. 505 f.). In the original *Inquiry*, Jenner vaguely refers to "prevailing notions" of such causal relation (Jenner 1801, p. 506, 1802a). But, what does that tell us about the accidentalness of the finding?

On the one hand, we might say that it can still be regarded as an accident that it was Jenner, who was around the dairies at the time. He has not chosen to be born and practice medicine in Gloucestershire in the second half of the eighteenth century in order to find a smallpox vaccine. In this manner, one might consider his luck circumstantial—he was at the right place, at the right time (Sand 2020; Williams and Nagel 1976). This relates to another sub-question about the intent (or lack thereof) that might have motivated his behavior at the time: Had he been consciously receptive of those notions? Keeping an open eye might as well count as an effort on his part. Walpole suggests with his illustrative example, taken from a fairy tale that was popular at the time about the Princes of Serendipity; the Princes were "not in quest of" the things they found on their journeys, and Compere assumes that since Jenner has made no effort to meet the milkmaid, he hadn't been on the lookout for vaccination either.

But this is a psychological hypothesis. Even if the "milkmaid myth" hawked by Baron and Compere, were true—which it probably isn't—we would have to determine, whether Jenner has been "in quest of a preventative treatment for smallpox" or in quest of anything at all, to definitely determine, whether this is a case of serendipity in the Walpolean sense. Answering this psychological question from our historical vantage point seems impossible. It is not unlikely, though, that he—like many other practicing physicians at the time—was very aware of the shortcomings of the established method of variolation and always more or less dedicatedly on the lookout for a better procedure—even if not necessarily in the place where he eventually found it. Thus, one might claim that he indeed "sought of" a way of improving the method of variolation, when (by accident) crossing the path with Andrew Fewster and the rumours that circulated at the time (though he might not have sought exactly the type of method that he found).

Donald Gillies presents a similar interpretation of Fleming's discovery of Penicillin: Fleming was on the lookout for antiseptic agents, though he didn't expect to find them in a mould that accidently showed up in his laboratory (Gillies 2015). That Jenner's sagacity played a role in the discovery seems less controversial: Jenner recognized the potential of the insight and dedicated to it his systematic attention, to become the most important and outspoken proponent of the procedure at the time (Baxby 1999).

There is another understanding of serendipity that equally—if not better—lends itself to this case: Serendipity as an emergent property of collective action (Copeland 2017). As mentioned above—in one way or another—Jenner was on the receiving end and entered in at a later stage of a discovery process that had originated in folk knowledge. Whether by repeated witnessing of farmers bragging about never having "an ugly pockmarked face", by being confronted with rumours in the dairies or contact with Fewster, Jenner was led by others on the trail of cowpox inoculation (Barquet and Domingo 1997, p. 639). Furthermore, aside from the previously

mentioned patronage that helped to secure continuous support of Jenner's ideas (they were fragile in their beginnings to say the least) (Baron 2014; Bazin 2000; Burrell and Kelly 2014, p. 876), this points to a collective genealogy of the 'eureka' (serendipitous) moment in this discovery.

Further, making vaccination a commonplace in modern times included much more than detecting its basic principle: It relied on the experiences, lore, support and patronage of other unacknowledged people. That is, the global success of vaccination that ultimately led to the first and only eradication of a disease required more than just the discovery of the basic technique of vaccination or even a number of prominent proponents: As Andrea Rusnock (2009) reminds us, it was no small feat to actually gather and deliver suitable cowpox material to provide vaccination in the early days, another reason to adhere to a human-to-human transmission of pox material (see also Bazin 2000, p. 185):

> The concerted effort to spread cowpox as a beneficial prophylaxis thus provides a very different perspective on the globalization of disease. Exploring how Europeans and their colonial allies transported and maintained cowpox in new environments is a social and technological story involving a broad range of individuals from physicians and surgeons to philanthropists, clergy, and colonial administrators. (Rusnock 2009, p. 18)

To cope with the initial flaws of the procedure—its susceptibility to transmit other viruses and bacteria—improvements in hygiene and new sterilization techniques were required. Those were discovered around the middle of the nineteenth century by Ignaz Semmelweis and Joseph Lister (Lister 1867). It nevertheless took until the early twentieth century before those flaws were entirely eliminated from the procedure. Most importantly, the concerted and global effort beginning in the 1960s of the WHO included training laypeople how to vaccinate and policies that managed to reach the most rural areas of the world (Williams 2010). This was a "unique" and exceptional global effort that could have failed at more than one point and, in fact, almost did fail (Barrett 2007).

Only through these collective and incremental efforts (in a diachronic and synchronic sense) could vaccination against smallpox become a pillar of global health. In this manner, as Copeland writes, serendipity becomes an emergent property of a complex process that involves various actors and their diverse relationships (Copeland 2017, 2018). Seen from this intriguing perspective, we recognize that the medical procedure of vaccination itself is not a static, separate artefact that maintained a concise form or shape over the centuries. Through its embedding in society, its various regulations and the impact of related medical practices and knowledge, its guise and impact on society changed over time. Vaccination is in a sense a dynamic artefact and a constant production of many hands (van de Poel 2015).

In many instances, in which individuals are singled out to be attributed the status of the sole discoverer, this represents the forceful reduction of the historical complexities of the process of discovery (Schaffer 1986). What is considered a discovery, a finding that is in some way significant, can be acknowledged as being significant only after it is contextualised by others, calibrated by others in relation to existing knowledge and artefacts, being credited by others as a novelty and diffused by others to receive

wider social recognition. A discovery is in this manner always distributed amongst the behaviour of several individuals, various locations and moments in time. In any of the aforementioned phases, luck can—and most likely will—play a role. Consequently, we can assume that serendipitous discovery is rather the norm than the exception: The majority of known discoveries went through the aforementioned steps, thus containing facets that were uncontrolled and unforeseen (Trout 2016, 2019).

Moral Luck and Individual Responsibility

In the following, we will focus on the aspect of luck—not so much in the unexpected occurrence of an insight that Jenner managed more or less well to capitalize on—but also the plain luck that this was indeed not just a baseless hunch that one disease could protect from contracting another, but a real insight whose underlying mechanism was only decades later fully understood. Furthermore, we want to consider the luck that led vaccination to become a global success story despite the procedures' initial flaws, some of them caused by Jenner himself. Each of these developments seems to have affected positively the way in which we evaluate Jenner's decision today and elevated his recognition and status as a scientist. Had the experiment not succeeded, which—as he himself anxiously recognized—was a very real possibility and which was beyond certainty and control, we would assess him differently today. As mentioned before, it seems that this luck has a moral dimension as it affected our ultimate evaluation of Jenner's scientific merits and desert, which are expressed in the public commemorations of his achievements.

We shall begin with the first recorded vaccination experiment from 1796, which he describes in his *Inquiry*. The experiment is described in Jenner's original publication from 1798 on page 20 to 22 as case 17. The case descriptions before this one document circumstantial observations: They present Jenner's recollection of patients, who contracted the cowpox and who assured him that even during latent smallpox surges, they didn't contract the disease. Based on this, he forms the intention to prove that there is indeed a connection between contracting cowpox and being immune to smallpox. We can read:

> The more accurately to observe the progress of the infection, I selected a healthy boy, about eight years old, for the purpose of inoculation for the Cowpox. The matter was […] inserted, on the 14th of May, 1796, into the arm of the boy by means of two superficial incisions […]. On the seventh day he complained of uneasiness in the axilla, and on the ninth he became a little chilly, lost his appetite, and had a light headache […]. In order to ascertain whether the boy, after feeling so light an affection of the system from the Cow Pox virus, was secure from the contagion of the Small Pox, he was inoculated on the 1st of July following with variolous matter. Several light punctures and incisions were made on both his arms, and the matter was carefully inserted, but no disease followed. (Jenner 1802b, pp. 20-22)

This experiment can rightly be considered dubious: On a thin evidential basis (Baxby calls it "scanty"; Baxby 1999, p. 302,), Jenner put the life of a boy at risk. Children are highly vulnerable research subjects, since they cannot properly assess the risks entailed in a study—hence, their capacity for informed consent is limited. Furthermore, children were much more likely to die from smallpox than adults (Baxby 1999), of which Jenner must have been aware. So, why choose a healthy child? In

his own account presented in *On the origin of the Vaccine Inoculation*, he notes the anxiety and uncertainty that preceded the experiment:

> During the investigation of the Cow-pox, I was struck with the idea that it might be practicable to propagate the disease by inoculation, after the manner of the Small-pox, first from the Cow, and finally from one human being to another. I anxiously waited some time for an opportunity of putting this theory to the test. At length the period arrived. [After the experiment,] I could *scarcely* persuade myself the patient was secure from the Small-pox. (Jenner 1801, own emphasis, p. 507)

Bazin, a chronicler of smallpox, suggests that "what we know of [Jenner's] work in no way indicates that he transgressed the morality of his period (and probably also of the present day), considering what was known at that time". (Bazin 2000, p. 186) Yet, Bazin notes that "[t]here had been a little more risk for James [more than for Sarah Nelmes—the milkmaid, from whom the cowpox material was taken] but it was, nevertheless, fairly limited" (p. 38). In general agreement with this, Hugh Davies argues that in this case the benefits clearly outweighed the risks. He writes that Jenner's experiment "addressed a major risk to the health of the community, and, given the devastating nature of smallpox and the significant risk of variolation, the only alternative preventative measure, Jenner's study had purpose, justification and a base in the practice of the day". (Davies 2007, p. 174) It should be clear that such utilitarian reasoning would by no means be acceptable nowadays to justify unconsented medical experiments with vulnerable populations. Has it been during his day and age? Furthermore, even if we accept the general view that some major potential benefits outweigh some minor risks, this only justifies the general motivation behind the experiment and not the manner in which it was conducted. There were alternatives that would have mitigated the risks to some extent—we will allude to those in a moment.

Clearly, one might object that we are assessing him uncharitably according to rather recently established bioethical standards, which did not prevail during his time. Considering his work from the vantage point of today means doing him a great injustice. We argue, however, while biomedical regulations and the method of systematic animal trials did not exist at the time, a debate about good medical practice had begun to flourish: In the treatises of John Gregory, a Scottish contemporary of Jenner, we find admonitions to doctors to not capitalize on the vulnerability of their poorer patients (McCullough 1998; Strätling 1997; Truman 1995). Gregory also suggested that doctors should never recommend medical treatments that they wouldn't use on themselves or their own children. Jenner abided by neither of those admonitions. He tested vaccination on Phipps two years before he tested it on his own children and Phipps was the son of his penniless gardener (Williams 2010). Whether Jenner offered a financial incentive to participate is unknown. It is unlikely though, given the dependence of medical practitioners on their oftentimes financially affluent aristocratic patrons and donors, that Jenner would have chosen a child from a more affluent family for the experiment (Jewson 1974). It is not unlikely that there was at least implicit pressure for Phipps' parents to let their child participate, which capitalizes on their vulnerability and undermines their autonomy for informed consent.

One might compare Jenner's approach to that of Lady Montague, who decided to prove her conviction in the efficacy of variolation by first variolating her **own** child.[7] This left a decent impression on the British aristocracy at the time. However, the royal family of George III. still did not entirely trust the procedure. The devastating outlook of contracting smallpox did not convince everyone to try whatever new procedure was in fashion.[8] They decided to test the efficacy of variolation on several adult prisoners first (Bazin 2000, p. 13).

What does that show? On the one hand, that adults, if they were not inoculated before, were to some extent considered as suitable research subjects, too. It shows, on the other hand, that the danger of these sorts of medical "experiments" were known and people consciously considered how to mitigate the risks for those societal members who allegedly mattered most—in this case the royal children. Exposing people to such risks was reserved for those who mattered less in the public eye: Prisoners awaiting capital punishment belonged to this group.[9] Surely, that is not an ethical choice either: Here too, pressure has likely undermined the autonomy of the research subjects for legitimate consent. But the case serves to show that the awareness of the risks for research participants and mitigating strategies existed at the time. In 1796, Jenner had been waiting for some time for the cowpox to return to Gloucestershire. To not miss the opportunity, he probably took the next best subject available to him—someone who had not yet been variolated by the Suttons: It was a choice of impatience and maybe convenience. Conclusively, it is fair to say that Jenner imposed a considerable risk on the research subject. Alternative designs for the experiment, which might have mitigated the risks involved in the procedure also from his viewpoint, were comfortably available to him; a more mindful approach to the testing of inoculation was thus a concrete option he discounted for the sake of pursuing success (Sand et al. 2019).[10]

As the experiment succeeded and Phipps survived and became immune to smallpox, the public recollection tends to focus primarily on celebrating the massive, positive impact Jenner's innovation had on public health. The dubiousness of this practice has vanished from public recollection. Jenner received all the big honours suitable for someone who is considered a medical revolutionary. A society and an institute were dedicated in his honour, towns and streets were named after him, several statues were erected (most notably the one in Kensington Garden, which stood originally at Trafalgar Square) and several biographies have been written. Current

[7] "On returning to England, Lady Montagu had her daughter inoculated with smallpox in public, by her surgeon, "Doctor" Maitland, in order to show, by example, the advantage of the method. […] Lady Mary was a capable woman- and brave, for the risks were very real!" (Bazin 2000, p. 12 f.).

[8] In times of enormous qualitative diversity in medical practice, awareness of the widespread charlatanry was important (Jewson 1974).

[9] As the royal family still didn't feel 100% sure about the procedure, they accepted orphans as research participants in the following step.

[10] Note, this does not imply making Jenner a moral and scientific outcast and erasing him from scientific history. Our plea for a balanced assessment is most difficult to convey as it draws a picture beyond a binary scheme of good and bad: The dubiousness that we underscore must be as much part of the evaluation as his awareness and recognition of the potential of the method at hand.

commentators—even those who highlight the role of the other contributors to the success of vaccination—predominantly praise Jenner and argue that he deserves to be called a medical "hero" amongst others (e.g. Andrew Fewster) (Gross and Sepkowitz 1998), and his "life story remains an inspiration to physicians". (Willis 1997). In an overall extremely balanced account of the history of smallpox *Angel of Death*, we cannot find any hint that Jenner's experiment was morally dubious (Williams 2010). It is only Royston Roberts who wonders "how he [Jenner] persuaded the boy and his parents to take such a chance". (Roberts 1989, p. 21).

Conclusively, to put it in terms of a famous notion of Bernard Williams; success gave him right (Williams and Nagel 1976). James Phipps was not harmed—though the possibility of him passing away due to an unknown health issue is easily conceivable. Because he was not harmed, Jenner using him as a guinea-pig seems less relevant or even irrelevant to an evaluation of his doing so. The fact that Jenner succeeded in an experiment of which he couldn't have known with certainty that it would succeed, makes him morally lucky. The "success though lucky" state overshadows his thoughtless experimental design and the prematurity of his 1798 publication. Are these such evaluations in hindsight justifiable, given the lack of control that he had over the subsequent events including the necessary contributions by others to the success of vaccination? What weight should these things beyond his control have on the way we commemorate him? It is clear that in a counterfactual world, in which vaccination would have turned out to be a fluke and Phipps had died, or vaccinations' advocacy had ebbed away due to the devastating side-effects of the original procedure, his reputation would be a different one: No Jenner institute, no fame, no statues. Can such a paradox of moral luck be avoided?

Moral Luck and Value Trade-offs in Science Stratification

Philosophers have wrestled with the problem of moral luck over millennia: People ought not to be assessed for things beyond their control, but they apparently are assessed for exactly such things (Williams and Nagel 1976). Jenner is commemorated for the success of vaccination, although he could not have been certain, nor has he alone brought it about. Luck is in this manner often seen as an adversary to moral responsibility: If accidents occur, no one should be held responsible. Thus, if serendipitous discoveries are in fact substantively accidents, we must refrain from praising people for "making" such discoveries. And why should we refrain from assessing someone for things beyond her control—for being lucky? It might be suggested that this would be unfair: It is unfair that some people fail in their endeavors and others succeed owing to luck and we take this into consideration in our allocation of praise and blame—some are not in quest of something, but find it, others are also not in quest of something and it is only lack of luck that stops them stumbling over it.

In this particular case, it is difficult to imagine who the complainant would be: If fairness is a problem, it seems less so in cases of praise and commemoration. There is an asymmetry between praise and blame in this regard: *Prima facie*, praise does not really harm anyone and neither does the omission of praising (King 2014). Hence, unlike someone who is punished for things beyond control, Jenner has no reason for complaint: He was not assailed by anything adverse to his interests for things beyond

his control. Neither did anyone else have to incur harm as a result of the praise he received.

Or so it seems: But, what about other people, whose relative standing might be denigrated in comparison? Clearly, there is no counterfactual Jenner, who is identical in all regards to the actual Jenner, and whose experiment failed, and who could now complain that he was just unlucky and must be treated equally for fairness reasons. This could mean that neither the actual nor the counterfactual Jenner receives praise and rewards, or that both do. Surely, in real life, such comparisons between real and fictitious people are highly speculative: Was there another keen-eyed, sagacious physician in Europe at the time, who would have rightly assessed the gravity of this notion, had she been in contact with the rumors in the dairies? Someone who thus deserves to be praised too, given that this was a matter of circumstantial luck—beyond both their control. Whether such a person existed, we will never know.

We write the history of medical innovation after the fact, once the success has occurred. A successful innovation, even if partially lucky, provides evidence that indeed someone has had the laudable skills and virtues that were required to recognize its value. Luck, thus, provides evidence for the existence of admirable traits—such as Jenner's sagacity. Without such evidence, without having a recognizable social impact of an innovation, we can only speculate about an agent's laudable traits (Rescher 1995).

But, it doesn't seem that Nobel Prizes are granted only for such epistemic reasons to those who have "conferred the greatest to mankind". (Nobel 1895) The rewards fulfill important societal functions and here the visible impact on society might be crucial for their efficacy. Prizes are supposed to encourage and incentivize the pursuit of desirable research and the best way to achieve this might be to link them directly to such type of research, lucky or not (Sand 2020). This is not limited to Nobel Prizes—it might also appertain to the aforementioned ways in which Jenner was (and still is) publicly commemorated with statues and streets named after him.

Harriet Zuckerman has suggested that "[rewards in science] serve much the same purpose as they do in other institutional spheres. They *validate past performance and provide a degree of motivation for the future* [own emphasis]. They bring attention to performance judged to be of high quality, thereby reinforcing the standards by which performance is to be assessed". (Zuckerman 1970, p. 252) Equally, in Responsible Research and Innovation (RRI), which has been a leading science and innovation governance programme in the European Union, the explicit goal is to "invite, accommodate, stimulate, enhance, foster and incentivize responsible action", following the Directorate General for Research and Innovation (van de Poel and Sand 2021). It might seem, thus, that there is a justification for focussing on the outcomes of Jenner's work despite the involvement of luck. Not only is it difficult if not impossible to identify those sagacious researchers and innovators, whose work remained incomplete and unsuccessful for absence of evidence that luck could have made a difference. Serendipitous discoveries can also be used to showcase the type of endeavours and outputs that society values and aims to foster.

There remains a caveat though: Zuckerman also suggests that stratification validates past performance. But, Jenner's past performance, as we have seen, boils

down to the sagacity of acknowledging the potential of vaccination and prematurely publishing results of his experiments, which were impatiently and thoughtlessly cobbled together. This sounds less exuberant and much more sober than viewing him hyperbolically as a "medical hero". Reward policies such as memorials, prizes and statutes aim at incentivizing and validating individuals' responsibility. These tools are too crude to convey a balanced assessment of their praiseworthiness (see also footnote 10). It seems that such instruments fulfil their societal function inevitably by distorting or at least simplifying the complex truth regarding people's desert.

A notable constructive suggestion to remedy some of those downsides is this: Validations of past performances could at least acknowledge that luck and serendipity in terms of the influence of other individuals, the accumulated knowledge available, the circumstances and results that fall beyond scientists' control, all contribute to successful "discoveries". This might still not convey a balanced assessment of Jenner's individual responsibility: A thick evaluation of his moral reasoning may even be beyond the grasp of present insight, as we suggested above. Yet, highlighting the role of luck and serendipity in this discovery could at least do justice to the complex historical, social and ethical genealogy of vaccination (Crawford 1998). We could, for instance, put Andrew Fewster, from whom Jenner learned about the possible relationship between cowpox and smallpox, up in the list of people who deserve more credit for their role in the history of vaccination. Or we might add early patrons of Jenner, who promoted the procedure and increased its public acceptance, to the list.

While this seems a creditable move towards a fairer distribution of responsibility, we must beware that it won't eradicate luck from the equation. Luck equally provides the preconditions required to bring an innovation collectively to fruition (Sand 2020). Scott Barrett points out that "[e]radication is a high stakes game, and could fail for any number of reasons. The ongoing effort to eradicate the regional disease, Guinea worm, for example, has been stopped in its tracks by the decades-long civil war in Sudan […]. The smallpox campaign was luckier. A ten-year cease-fire just happened to be in effect in Sudan during a key stage of the eradication effort: otherwise, eradication may not have been possible". (Barrett 2007, p. 180) Thus, there have been innumerable types of circumstantial and resultant luck involved in the collective endeavor of advocating and improving vaccination and fighting smallpox. In this manner, serendipity as a collective endeavor is no less accidental than the paradigmatic individual strike of serendipity (Chiapperino 2020). Here too, it will remain a constant challenge for the future of science stratification with regard to collective innovations to balance those different aims: being proportionate to the desert of individuals in those endeavors and showcasing what is valuable to effectively incentivize future innovation. It seems that this will always require drawing more or less arbitrary boundaries between an agent's contributions to an event that is societally relevant and desirable to be reproduced in kind, and the causal factors (including the actions of others) that were beyond this agent's control yet without which the event would not have occurred.

Conclusions

Serendipity and luck give rise to normative questions, of how we look at the moral standing of serendipitous individuals, how we separate their sagacity from the luck that led them to make their discoveries and the contributions of others that made their projects flourish. Incorporating this insight into the governance of science and science stratification is a challenge. Although it is suggested that focusing on luck can help us to make policies better to accommodate or eradicate it, it is by no means clear how to do this (Sauder 2020). There is a natural request that policies ought to be effective on the one hand and fair on the other: If they ought to be fair, they seem to require the eradication of luck from the picture. But, this seems impossible given luck's ubiquity that also appertains to collective efforts. To sum: Fairness would require rewards based on merit, but merit is not sufficient for reward (sometimes not even necessary); therefore, rewards are not fair, contrary to their meaningfulness. An ethics of serendipity will have to illuminate these issues on both a descriptive and normative level. On the descriptive level, we need a better understanding of the variety of contexts in which serendipity occurs and the manifold ways in which luck affects processes of discovery. Further, we need a more concise idea of how to identify the agential contributions to discovery and how to expand their scope of control. On the normative level, we need to consider the values of fairness and effectiveness and develop a theory that balances these and other values. It is unlikely that fairness is always overriding (Sand and Klenk 2021). Hence, a theory of just reward that takes serendipity and luck into account might at least provide a heuristic that indicates when fairness can reasonably be overridden and when not. These are the key challenges for any future ethics of serendipity.

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