

# How to Attack a Scientific Theory and Get Away with It (Usually): The Attempt to Destroy an Origin-of-AIDS Hypothesis

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**ABSTRACT** *Supporters of dominant scientific theories sometimes attack competing, less favoured theories in ways that conflict with expectations of proper scientific behaviour, for example by using double standards. To reduce concern about their actions, supporters can use a variety of techniques: cover up the violation of expectations; devalue the competing theory and its advocates; interpret the process as proper; use expert panels, meetings and other formal processes to give a stamp of approval to the dominant view; and intimidate opponents. These are the same five methods used regularly by perpetrators of actions widely seen as unjust, such as violent attacks on peaceful protesters. When these methods fail, the attack can backfire on the attackers. Orthodox scientists' treatment of the theory that AIDS originated from contaminated polio vaccines used in Africa in the 1950s illustrates how this framework can be applied to science. Opponents of this theory have used all five methods of inhibiting concern about violations of expected scientific behaviour. This analysis shows why supporters of orthodoxy have a tactical advantage over challengers.*

**KEY WORDS:** Scientific theories, disputes, controversies, tactics, origin of AIDS

## Introduction

In October 2008, a letter appeared in *Nature* arguing that the first human infection with HIV-1, the virus responsible for pandemic AIDS, occurred in the early 1900s, and certainly well before 1960 (Worobey *et al.*, 2008). Why was this significant?

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Because it implicitly challenged an unorthodox idea about the origin of AIDS, namely that it resulted from contaminated polio vaccines used in Africa in the late 1950s.

Scientists like Michael Worobey, lead author of the *Nature* letter, who advocate a ‘bushmeat’ theory of the origin of AIDS, have been trying to sink the polio-vaccine theory for over a decade. Their arguments are theoretical but they have managed to establish the bushmeat theory as the dominant view. Worobey’s piece in *Nature*, however, was not the final word. Soon afterwards, Edward Hooper, the principal advocate of the polio-vaccine theory, sent a brief reply to *Nature*, where it was rejected. (*Nature* had rejected five previous submissions by Hooper on the topic.) Hooper then submitted his reply to other journals but was told *Nature* was the appropriate venue. He also sent his reply to Worobey, inviting feedback, but Worobey did not respond (Edward Hooper, personal communication, 18 June 2009). So Hooper, to ensure his views were heard, posted a lengthy comment on his website (Hooper, 2008).

When a scientific theory, such as the bushmeat theory, becomes dominant, its supporters have powerful tools to marginalise challengers. In this article, I use this example to illustrate how defenders of dominant theories can get away with attacking competing theories in ways that seem to violate proper scientific behaviour.

Dominant scientific theories—supported by a large majority of experts in the field—are powerful tools for influencing policy. Some dominant theories serve the interests of powerful groups, helping to legitimise business as usual. For example, the dominant medical view about cancer legitimises conventional treatment using surgery, radiotherapy and chemotherapy, and thereby serves the interests of the medical profession and related industries.

Sometimes the dominant scientific view is a threat to powerful groups. For example, the orthodox view on the effects of smoking on health has been a potent tool used by anti-smoking campaigners against the tobacco industry.

Dominant scientific theories may be powerful tools, but when the theories are challenged, their power is potentially undermined. Critics of medical orthodoxy on cancer are a threat to the medical establishment. Therefore, it should not be surprising to find that defenders of scientific orthodoxy find ways of attacking or otherwise marginalising critics. But how can they do this in ways that seem compatible with the public image of science as objective?

Scientists usually say that theories should be evaluated using criteria such as agreement with facts, logical consistency, explanatory value, predictive capacity and simplicity. Many members of the public think this is the way science does or should operate, namely by discovering facts and evaluating competing explanations fairly.

This idealised image of science can cause difficulties for scientists when they appear to openly violate their espoused principles. If scientists and members of the public believe scientific theories are supposed to be judged according to the

evidence, then it looks bad when other factors seem to intrude—such as serving a vested interest. It looks bad when scientists subject a theory to excessive demands not required of competing theories, or when they reject submissions without a satisfactory explanation. These amount to dismissing a scientific theory unfairly or, in other words, displaying bias or double standards in evaluating theories.

Because so many people expect scientists to behave according to their espoused principles, scientists have incentives to minimise awareness or concern about any violations of these principles. The key question that I address is how scientists can attack a scientific theory in ways that violate the publicly espoused principles of scientific behaviour and yet avoid opprobrium for doing so. In other words, how do scientists attempt to crush an unwelcome theory and get away with it? And what can challengers do to defend their theory and counter the attackers' tactics?

I address these questions using a framework, called the backfire model, designed to highlight tactics used by perpetrators of what is potentially perceived as an injustice—in this case violation of common expectations about scientific behaviour. This framework is presented in the next section. To illustrate how to use the framework and to show tactics and counter-tactics, in the following sections I apply the backfire model to the theory that AIDS resulted from contaminated polio vaccines used in Africa in the 1950s. The conclusion discusses the implications of the analysis.

Before proceeding, it is important to acknowledge that sociologists and others, including some scientists, have for decades challenged the idealised model of science, revealing that the actual operation of science is not based on objective criteria to nearly the extent commonly imagined. Michael Polanyi (1958) said that commitment and indeed dogma were useful for the operation of science. Michael Mulkay and others argued that the high-minded norms proposed by Robert Merton (1973)—universalism, communism, disinterestedness and organised scepticism—do not describe science in practice (Mulkay, 1969, 1976; Barnes & Dolby, 1970). Ian Mitroff (1974) argued that counter-norms—for example, organised dogmatism as opposed to organised scepticism—described the operation of science as accurately as did Merton's norms.

Whereas Karl Popper (1972) argued that scientists should attempt to falsify theories, and many scientists adopted the rhetoric of falsification (Gilbert & Mulkay, 1984), Thomas Kuhn's (1970) concept of scientific paradigms challenged falsificationism. Subsequent analysts have developed a more nuanced picture of discipline- and situation-specific *ad hoc* rules that guide the day-to-day behaviour of scientists (Latour & Woolgar, 1979; Collins, 1985, 2004; Lynch, 1985; Pickering, 1995).

Sociologists of science certainly know that science doesn't operate according to objective criteria. There is plenty of evidence of specific biases, for example bias in support of papers confirming the currently accepted viewpoint and in favour of established researchers (Armstrong, 1997). But as long as significant numbers of people think science does or should operate in accordance with objective criteria,

then scientists need to manage people's potential adverse reactions to deviations from ideal practice. My focus here is not on the debate over how science actually operates but rather on tactics used by scientists to prevent or minimise perceptions of inappropriate behaviour.

### **Backfire**

Many people react negatively to something they perceive as unfair, unjust, excessive or a violation of a norm: they may become angry, upset, concerned or disgusted (Moore, 1978). An example is using violence against peaceful protesters. On 12 November 1991, in Dili, the capital of East Timor, thousands of protesters joined a funeral procession to Santa Cruz cemetery (Kohen, 1999). The protesters were surrounded by Indonesian troops: East Timor had been invaded by the Indonesian military in 1975 and occupied since then despite condemnation by the United Nations. As the protesters entered the cemetery, the troops opened fire without warning, killing many people.

Several western journalists attended the protest and witnessed the killing; some were beaten themselves. British filmmaker Max Stahl recorded the events on videotape, which he later smuggled out of the country. The reports by the journalists, plus Stahl's videotape, generated outrage internationally.

The shooting of the protesters was intended, by the Indonesian military, to intimidate East Timorese independence supporters, but instead, these events, called the Dili massacre, were highly counterproductive for the Indonesian government, greatly increasing the level of international support for East Timor's independence.

However, violent attacks on peaceful protesters are counterproductive on only some occasions. For example, there had been many massacres in East Timor before 1991 (Dunn, 2003, p. 292), but none generated much international concern. Furthermore, there are many other injustices perpetrated by powerful groups—beatings, torture, wars—that seem to cause little reaction. Therefore, it is plausible that perpetrators use techniques that reduce outrage or prevent its expression.

Looking at a wide range of cases (Martin, 2007), it is useful to classify the techniques used by perpetrators into five categories:

- cover up the action;
- devalue the target;
- reinterpret the events;
- use official channels to give an appearance of justice; and
- intimidate people involved.

Sometimes just one of these techniques is sufficient to prevent outrage. Massacres in East Timor prior to 1991 were covered up through censorship. In the case of the Dili massacre, however, cover-up failed, though not for want of trying:

international telephone links out of Dili were cut off immediately after the massacre and, acting on behalf of the Indonesian government, Australian customs officials searched Stahl's luggage for the videotapes on his arrival in Darwin (he had wisely entrusted the tapes with a friend who left East Timor by another route). With cover-up unsuccessful, the Indonesian government used the other four techniques of reducing outrage.

A leading Indonesian military figure, in a speech, referred to protesters as 'scum' and 'delinquents' (McMillan, 1992, p. 162). The Indonesian government spread false stories about the leader of the East Timorese resistance, to discredit him. These are examples of devaluation.

The Indonesian government used reinterpretation—namely, telling a different story about the events—when it claimed protesters had weapons, the shooting was spontaneous rather than planned and that 19 people had died, a figure later raised to 50. An independent study gave a total of 271.

The Indonesian government set up an inquiry into the events and found a few officials guilty of offences. The Indonesian military proceeded similarly. This was unprecedented: there had been no inquiries into previous atrocities. The officials and soldiers received short sentences and were let out early. In contrast, East Timorese activists charged with organising the protest received lengthy sentences. Due to this discrepancy in sentencing, many saw Indonesian inquiries as giving only a facade of justice.

The massacre was intended to deter East Timorese from protesting. Afterwards, Indonesian troops arrested, beat and killed a large number of East Timorese independence supporters. This was the tactic of intimidation.

The Indonesian government thus used each of the five methods of inhibiting outrage but, so far as international audiences were concerned, devaluation, reinterpretation, inquiries and intimidation had little impact (Hess & Martin, 2006; Martin, 2007, pp. 23–33).

The Dili massacre illustrates how an attack can backfire. It also illustrates the five methods by which a perpetrator can attempt to inhibit popular outrage against something perceived as unjust. This framework has been applied to a range of issues, including censorship (Jansen & Martin, 2003), corporate disasters (Engel & Martin, 2006), defamation (Gray & Martin, 2006), dismissals of academics (Martin, 2004), labour disputes (Smith & Martin, 2007), police beatings (Martin, 2005a), refugees (Herd, 2006), sexual harassment (Scott & Martin, 2006), torture technology (Martin & Wright, 2003), terrorism and war (Martin, 2007). These studies show that methods used by perpetrators can be conveniently classified into the same five categories.

## **Backfire in Science**

It seems promising, therefore, to attempt to apply the backfire framework to issues within science in which a powerful individual or group acts in a way potentially

perceived as unfair. Some possible issues are whistleblowing, scientific fraud, dismissals of scientists and allegedly unethical research. For example, whistleblowers are commonly subject to reprisals, with the employer using the five methods to inhibit outrage prompted both by the matter raised by the whistleblower and the subsequent treatment of the whistleblower (Martin with Rifkin, 2004; Martin, 2005b). The same dynamics can be expected when scientists are whistleblowers.

Here my focus is on scientific theories. If a scientific theory is treated in a way perceived as unfair or a violation of expectations about scientific behaviour, this has the potential of being counterproductive for critics of the theory, for example by giving more attention to the theory or creating more support for it. Therefore, according to the backfire model, it is to be expected that opponents of the theory, if they have sufficient power, will use one or more of the five methods for inhibiting outrage.

For this analysis to apply, it is not necessary for norms to be widely shared. As long as a substantial number of people believe something is unfair, dealing with outrage becomes a significant factor. For example, opinion polls show that a considerable proportion of people believe torture is justified in at least some circumstances, yet nearly all who practise something that could be construed as torture use one or more of the methods to inhibit outrage, because significant numbers of people are vocal in their opposition. It is to be expected that most perpetrators—such as torturers and torture administrators—believe what they do is acceptable; most outrage comes from targets and third parties. The same pattern certainly applies to science: even when most scientists endorsing a dominant theory have little problem with techniques used against challengers, they may need to address potential concern by others.

It is possible to distinguish, in principle, between tactics used to oppose a challenging theory, and tactics used to minimise concern about perceived norm violations in opposing the theory; but in practice there can be an overlap between these two types of tactics. For example, anonymous peer review can be used to marginalise a challenging theory and, at the same time, the secrecy involved can reduce awareness that anything improper might be involved.

This framework is principally used to analyse perceived injustices perpetrated by a powerful group against a less powerful target. The contrary case, in which the perpetrator is the weaker party, is seldom problematical: this regularly backfires. Most murderers are weak in relation to the justice system and hence have little chance of inhibiting outrage except by escaping detection and capture: the techniques of devaluation, reinterpretation, official channels and intimidation have little leverage against the police and the wider community. In looking at treatment of scientific theories, therefore, the main interest is when supporters of a dominant theory act against competing theories in ways potentially perceived as unfair.

Studies of scientific controversies illustrate a wide range of tactics. Collins and Pinch (1979) list a series of tactics used by parapsychologists and their critics,

most of which fit into the categories of reinterpretation and devaluation. Delborne (2008), in examining tactics used by several dissenting scientists in the field of agricultural biotechnology, introduces the idea of a spectrum of practices, ranging from ‘agonistic engagement’, using conventional means to gain credibility, to ‘dissident science’, which links intellectual struggle with social action.

The most well known general approach to tactics is actor–network theory, with its category of actors—both human and non-human actors, sometimes called actants—using methods of enrolment and translation, through which interests are constructed (Latour, 1987; Callon *et al.*, 1988). These general methods can be expressed in various ways. For example, actors can translate the interests of potential allies in particular directions by serving their needs, creating new needs, making themselves indispensable (as an ‘obligatory passage point’), or convincing them that a detour is needed to achieve their goals. The categories of actor–network theory are at a high level of abstraction: what they mean in practice is determined by close observation of case studies, through the process of ‘following the actors’, namely looking in minute detail at what they do, from conversations to investments. Actor–network categories are neutral in the sense that they do not reflect a moral judgement: the theory does not privilege particular actors.

The categories of the backfire model can be mapped onto actor–network categories. For example, devaluation and intimidation can be thought of as ways of discouraging enrolment by opponents, but there are some significant differences between the approaches. The backfire model is a low-level set of categories, designed for analysing a particular type of confrontation, namely where there is a potential perception of unfairness. Furthermore, three of the backfire methods—cover-up, devaluation and intimidation—are explicitly value-laden: these labels suggest impropriety. The backfire model is most suited for dealing with situations in which justice and norm violation are prominent frames, or in which the analyst wishes to highlight these frames.

To illustrate how the backfire framework can be applied to scientific controversies, I examine the treatment of the theory that AIDS originated from contaminated polio vaccines. I first learned about this theory from Louis Pascal in 1990 and have read numerous scientific and other publications about it. After publishing Pascal’s paper in 1991, I received correspondence from hundreds of individuals. In the years since then, I have published articles about the controversy (e.g. Martin, 1993a) that have led to further correspondence. Beginning in the mid-1990s, I have hosted a large collection of documents about the theory on my website, which leads to people contacting me with additional information and perspectives. In 2000 I attended a meeting of the Royal Society about the theory and gave a paper (Martin, 2001a). My most intense contacts have been with proponents of the theory, or those who think it has not received a fair hearing, including Louis Pascal, Julian Cribb, Tom Curtis and Edward Hooper.

Thus, as well as studying the controversy, I have personally intervened in it in a partisan fashion, especially to increase awareness of the way the theory has been

treated (Martin, 1993a, 2001b), and have reflected on this approach of partisan intervention (Martin, 1996), a process that has both strengths and limitations. My close involvement with the theory has given me access to much of the information that makes possible the analysis in this paper.

### **The Origin of AIDS**

AIDS is a new human disease, first recognised in 1981. Therefore, to ask how it arose is an obvious question. This question has practical as well as intellectual interest: the process of understanding the origins of diseases is often helpful in learning how to deal with them and to prevent further new diseases.

The dominant theory—accepted by most scientists—is that AIDS is due to a virus, called the human immunodeficiency virus or HIV. Actually, there are many variants of HIV; the one deemed responsible for the AIDS pandemic is called HIV-1M. HIVs are similar to simian immunodeficiency viruses, or SIVs, found in monkeys and chimpanzees. The standard explanation for how AIDS began is that a human became infected with an SIV that became transmissible among humans. Of the SIVs discovered so far, the ones closest to HIV-1M have been found in chimpanzees in central Africa. Various transmission routes have been proposed: a chimp might have bitten a human; chimp blood might have been injected during sexual rites; a hunter, in butchering a chimp, might have got chimp blood in a cut; or undercooked chimp flesh might have been consumed. This theory has been called the natural transfer theory, the cut-hunter theory or the bushmeat theory. The latter two names imply a transmission via hunting or eating but are metonyms for other routes such as a monkey bite.

I focus on the challenging theory that has received the most attention within the scientific community, which postulates that AIDS originated from contaminated polio vaccines given to a million people in central Africa during 1957–1960. This was the world's first mass vaccination campaign against polio, led by Hilary Koprowski, from the Wistar Institute in Philadelphia. Koprowski is one of the world's three polio pioneers, though he is not as well known as the other two, Jonas Salk and Albert Sabin.

Salk's vaccines were based on killed polio virus, which has to be injected, whereas both Sabin and Koprowski used live virus, taken orally. The theory that AIDS developed from contaminated polio vaccines is called the polio-vaccine theory or the OPV theory, for oral polio vaccine.

In the 1950s, polio vaccines were cultured—grown—in diced-up monkey kidneys; indeed, many of today's polio vaccines are still cultured in monkey kidneys. When using a live attenuated polio virus as a vaccine, it is possible that other viruses in white blood cells from the culture, monkey kidneys, could contaminate this vaccine. Monkeys harbouring SIVs endemic to their own species do not show signs of disease, so kidneys of such healthy animals might quite readily have been used to culture the polio virus. The possibility of



monkey viruses contaminating vaccines is more than hypothetical, for it happened in the years 1953–1962: a monkey virus named SV40—the 40th simian virus discovered—contaminated batches of polio vaccine given to hundreds of millions of people (Shah & Nathanson, 1976).

In the 1950s, SIVs were unknown, so there would have been no reason to screen for them. Indeed, SIVs were not discovered until 1985, subsequent to the discovery of HIVs.

Between 1957 and 1960, Koprowski's vaccine was given to nearly a million people in central Africa, in what was then called the Belgian Congo (later Zaire and today the Democratic Republic of Congo) and Ruanda–Urundi (today Rwanda and Burundi). This part of Africa is precisely the area where the earliest known cases of AIDS and HIV-positive blood are located. The two earliest HIV-positive blood samples date from 1959 and 1960 in Leopoldville in the Belgian Congo (now Kinshasa in the Democratic Republic of Congo), where one of the polio trials was held. All the world's earliest AIDS cases occurred either in central Africa or in individuals with direct links to central Africa. Thus, the OPV theory is compatible with, indeed might explain, both the location and timing of AIDS' origin, and its proposed mechanism—the contamination of polio vaccines with a simian virus—is known to have operated in the case of SV40.

The two competing theories—bushmeat and OPV—have been in a bitter struggle since the early 1990s. As occurs regularly in controversies, proponents of each theory have used many different methods to wage the struggle. Some of these, such as publishing scientific papers, are compatible with common expectations about the operation of science, but others are not. I focus here on the view that opponents of the OPV theory have shown serious bias. In terms of Merton's norms, they have seriously departed from the norm of organised scepticism, showing little scepticism towards the bushmeat theory, and from the norm of disinterestedness, in that they have an interest in opposing the OPV theory. In terms of Popper's falsificationism, they have conscientiously attempted to falsify the OPV theory but have never tried to falsify the bushmeat theory.

This sort of bias is commonplace in scientific disputes, but seldom do scientists openly admit to serious departures from expectations about scientific behaviour. In this circumstance, the backfire model predicts that the dominant group will use one or more of the five methods to inhibit concern about departures from expected behaviour: cover up the actions; devalue the opposing side; reinterpret the issues at stake; use official channels to give an appearance of fair treatment; and use intimidation. Note that backfire analysis can be carried out even when behaviours do not backfire—indeed, that is the most common scenario.

In the following sections, I present examples concerning each of these five methods, and counters to them, telling more about the origin-of-AIDS debate along the way. Given the complexity of the debate, only a portion of available evidence will be used. I use 'OPV-theory proponents' and 'OPV-theory supporters'

as shorthand to include both advocates of the OPV theory and those—like Tom Curtis, W.D. Hamilton and myself—who believe it has not received a fair hearing.

### Cover-up

One of the major obstacles faced by OPV-theory proponents has been getting published, especially in scientific journals. Critics of the OPV theory, in contrast, have had many scientific publications.<sup>1</sup>

The first person to develop the polio-vaccine theory was an independent scholar working in New York City who calls himself Louis Pascal. In the late 1980s, he wrote an article about it that was rejected by *Nature*, *New Scientist* and *The Lancet*. He later wrote a much lengthier treatment that was rejected by the *Journal of Medical Ethics* for being too long (Gillon, 1992). I then arranged for the latter paper to be published in December 1991 in a working paper series at the University of Wollongong (Pascal, 1991). The paper received wide circulation, especially following a supportive editorial in the *Journal of Medical Ethics* (Gillon, 1992).

Blaine Elswood, an AIDS activist from San Francisco, around 1990 independently developed a version of the polio-vaccine theory and, in collaboration with scientist Raphael Stricker, submitted a paper to *Research in Virology*. After initial enthusiasm, the editor asked them to pare the paper back to letter length. When it was eventually published (Elswood & Stricker, 1993), the letter was accompanied by a disavowal by the journal's editorial board—quite an unusual treatment.

Elswood told Texas-based journalist Tom Curtis about the OPV theory; Curtis followed up with further investigation, including interviews with Koprowski, Sabin, Salk and other scientists, and wrote a powerful story published in the rock magazine *Rolling Stone* that included eminent scientists' strong criticisms of the theory juxtaposed with circumstantial arguments in its favour (Curtis, 1992a). The *Rolling Stone* article had a tremendous impact, generating comment in both scientific journals and the mass media. After an article critical of his story appeared in *Science*, Curtis wrote a letter to the editor that was published there (Curtis, 1992b). Koprowski (1992) then replied in *Science*; Curtis's response to Koprowski (Curtis, 1996) was refused publication, so Koprowski's letter appeared definitive.

W.D. Hamilton, professor of zoology at Oxford University, was considered by many to be the leading evolutionary biologist of the twentieth century; he won several prestigious prizes (Hamilton, 1996–2005). He was by far the highest profile scientist to support investigation of the OPV theory. In 1994, he wrote a letter to the editor of *Science*, in effect a reply to Koprowski (1992), arguing that the OPV theory deserved consideration. His letter was rejected. Hamilton wrote an eloquent appeal to the letters editor to reconsider this decision, to no

avail (Hamilton, 1996). Thus, someone examining the origin-of-AIDS issue in the pages of *Science* would, in the mid-1990s, have seen no rebuttal to Koprowski's 1992 letter: Curtis's and Hamilton's responses had been rejected.

Was this treatment of OPV-theory submissions to scientific journals based on merit, or did it reflect a bias? Answering this question, or a more constructivist version of it, is made more difficult by the secrecy of peer review, including the anonymity of referees and the lack of explicit justification for some decisions by editors.

Curtis also wrote articles for the *Houston Post*, including ones reporting on calls for the Wistar Institute to release samples of polio vaccine for independent testing (Curtis, 1992c). Based on what Curtis was told by Koprowski, OPV-theory proponents thought at the time that polio vaccines were manufactured in the United States and then shipped to Africa to be used. In interviews for the *Rolling Stone* story, Koprowski told Curtis that samples of his African polio vaccine were held in freezers at the Wistar Institute. Curtis therefore assumed that testing of these samples might reveal evidence of SIV and the monkey species used. However, despite the Wistar's offer in 1992 to provide samples for independent testing, apparently no tests were carried out at that time and no reports of any tests were published for a further eight years.

In 1990, Edward Hooper, a writer and former journalist based in England, began an exhaustive investigation into the origins of AIDS. Within a couple of years, he decided the OPV theory was the most plausible candidate and pursued relevant information relentlessly, delving into archives, interviewing scientists and others around the world, and putting together an account of the early history of AIDS. Among the new information he discovered was that chimpanzee kidneys had been flown from Africa to the US during the late 1950s, thus providing a possible route for chimp SIVs to enter polio vaccines manufactured in Philadelphia. Hooper obtained valuable scientific assistance from Hamilton.

The result of Hooper's labours was a mammoth book, *The River*, published in Britain and the US in 1999. It read like a scientific thriller and soon attracted a large readership and received reviews in dozens of leading scientific and popular media, for example *Nature*, *Science*, and the *New York Times*.<sup>2</sup>

The higher visibility of the OPV theory, largely due to Hooper's work, led a French/Canadian team to make a film titled *The Origins of AIDS*, presenting both sides of the debate, but mostly supportive of the OPV theory. Released in 2003, *The Origins of AIDS* won several film and science prizes and has been shown on television in many countries. Behind the scenes, leading scientists opposed to the OPV theory wrote letters to film festival directors and television executives attacking the film and urging them not to screen it.<sup>3</sup>

In summary, opponents of the OPV theory have tried to limit awareness of it by blocking publications in scientific journals, failing to carry out relevant scientific testing (throughout the 1990s), and attempting to limit screenings of the film. Blocking scientific publications by use of peer review and editorial discretion is

normally seen as legitimate, assuming decisions are made on scientific grounds, but because the process is carried out largely in secret, it is difficult to judge whether anything improper has occurred. Failing to carry out obviously relevant testing—notably of polio vaccine samples held at the Wistar Institute—violates the expectation that evidence be the basis for rejecting a theory, but this expectation is less imperative for theories perceived to have low credibility, so during the 1990s this aspect of cover-up did not cause significant concern. Finally, the letters to film festival directors and television executives are an obvious attempt to reduce attention given to the OPV theory. That the scientists and lawyers writing these letters have not made their claims in public is compatible with the inference that they do not want to expose either their claims, or their attempt at what might be interpreted as censorship, to public scrutiny.

### **Devaluation**

The second method perpetrators commonly use to reduce outrage over perceived injustices is devaluing the target. If the target is a scientific theory, this could involve denigrating the theory itself or its proponents.

The rhetoric of science is that ideas are evaluated dispassionately, without regard to what they are or who advocates them, but this is routinely violated. Whole areas are written off as unworthy, such as parapsychology, cold fusion and homoeopathy, and ideas from individuals without scientific training or institutional affiliation are often dismissed out of hand.

It so happens that most of the leading proponents of the OPV theory have not been professional scientists: Pascal, an independent scholar; Elsworth, an AIDS activist; Curtis, a journalist; and Hooper, a writer. Their most influential contributions have been published in non-peer-reviewed forums. Therefore, both they and their writings would seem obvious targets for devaluation. There are a couple of examples of this in scientific publications. Koprowski began his 1992 letter to *Science* as follows:

As a scientist, I did not intend to debate Tom Curtis when he presented his hypothesis about the origin of AIDS in *Rolling Stone*. The publication of his letter in *Science* (29 May, p. 1260), however, transferred the debate from the lay press to a highly respected scientific journal. I would now like to state my views, based on facts, in order to counter and thereby repudiate Curtis' hypothesis about the origin of AIDS.

Koprowski implies that ideas not presented in scientific forums are not worthy of consideration.

Robin Weiss, a professor in the Department of Immunology and Molecular Pathology, University College London, a leading figure in the debate, has presented himself as an objective commentator. He wrote in *Nature* in 2001 that

‘some beautiful facts have destroyed an ugly theory’, referring to evidence that he said showed the OPV theory was wrong. Weiss’s comment is an inversion of a well-known expression that ‘some ugly facts have destroyed a beautiful theory’. This may reflect a certain mischievous attitude, but it is also compatible with an attitude that the OPV theory is ‘ugly’, namely undesirable.

These comments by Koprowski and Weiss are exceptions to scientific discourse, which mostly avoids derogatory expressions. Behind the scenes, in private conversations and correspondence, much more dismissive and even vicious expressions are commonplace, as is known to most scientists and as documented by Mitroff (1974). The same applies to the OPV theory.

Opponents of the OPV theory have claimed, on occasion, that the theory is harmful to public health by undermining polio vaccination campaigns in Africa and giving support to public resistance to vaccination.<sup>4</sup> The letter by OPV-theory opponents to film directors states that the ‘film serves to promote the rumor that the current oral polio vaccine contains the virus of AIDS, a rumor that has influenced Nigerians to stop vaccination’ and ‘the film plays into the anti-vaccinationism that has had bad effects in many countries, leading to problems such as the recrudescence of measles and mumps in the United Kingdom’. OPV-theory opponents have never provided any solid evidence that the theory has hindered current polio vaccination campaigns.<sup>5</sup>

In summary, devaluation undoubtedly plays a role in attacks on the OPV theory, but there is little evidence of this on the public record. Its main significance is in behind-the-scenes discourse, such as the letters to film festival directors and television executives, but without more information it is difficult to judge the significance of the factor.

## **Reinterpretation**

The choice of what to observe or measure, the turning of observations into data, the assessment of the significance of evidence, views about what counts as support for a theory: these and other processes of interpretation are at the core of scientific engagement with theory and observation. These processes can be used against competing theories, sometimes in ways that might be seen by observers as biased.

The most effective explanatory tactic used by opponents of the OPV theory has been to assume the bushmeat theory is the default option, to be accepted if competing theories have any flaws. The onus of proof has been put on the OPV theory to pass strenuous tests whereas the bushmeat theory has been given little critical scrutiny (Martin, 2001a). A one-sided onus of proof is compatible with the idea that ‘extraordinary claims require extraordinary proof’, but this assumes a benchmark of well-tested theory against which challenging views can be said to be ‘extraordinary’. Yet the bushmeat theory is so undeveloped that it is difficult to point to evidence supporting it. It is based on the assumption that SIV entered humans

from chimpanzees via an unknown interaction, perhaps in the early 1900s in southern Cameroon, and that it then became transmissible in humans. It gives no explanation for why this occurred so recently, given millions of years of human–chimpanzee interaction, other than to assume AIDS remained localised and undetected until increased commerce and urbanisation promoted spread of the disease. (However, commerce and mass movements of people in Africa go back centuries, including the slave trade.) It gives no explanation for the dates and locations of early HIV-positive blood samples and early AIDS cases and their apparent correlation with the dates and locations of Koprowski's African OPV trials.

Given the lack of specificity of the bushmeat theory, and the lack of evidence to support it, there seems to be no scientific reason why it has been taken as the default option. The assignment of the de-facto onus of proof to the OPV theory therefore can be seen as a highly successful tactic by its opponents. One outcome of this success is that nearly all the writing on this debate is for or against the OPV theory, with little attention to the strengths and weaknesses of the bushmeat theory.

Opponents of the OPV theory have claimed on several occasions that it has been refuted. For example, following publication of *The River* in 1999, the Wistar Institute released samples of polio vaccine for testing. The tests showed no evidence of HIV or SIV or chimp DNA. The results were announced at the Royal Society meeting in 2000 and published in 2001, trumpeted as providing a definitive refutation of the OPV theory. Robin Weiss's (2001) commentary in *Nature*, accompanying technical reports of the Wistar sample testing, was titled 'Polio vaccines exonerated'. Yet an elementary examination of these claims shows their weakness. Only some polio vaccines from the Wistar freezers were analysed: no evidence was presented that these were ones used in Africa. It remained possible that other Wistar vaccines, perhaps ones subsequently destroyed or degraded, had been contaminated with chimp SIV. If tests of Wistar vaccine samples had detected SIV, this would have been powerful evidence for the OPV theory, but a negative result was hardly a fatal blow to the theory.

Furthermore, soon after the Royal Society meeting, Hooper presented new evidence that Wistar vaccines had been amplified locally in Africa using chimp kidneys as the culture. With this new evidence, contamination of the original Wistar vaccines, in Philadelphia, was no longer hypothesised or required: Hooper posited that contamination instead occurred at Camp Lindi, near Stanleyville (now Kisangani) in the Congo, where in the late-1950s hundreds of chimps were kept by the Wistar Institute for experiments, and at a nearby lab, the Laboratoire Medical de Stanleyville; Hooper reported that nearly all the Lindi chimps were eventually sacrificed (Hooper, 2003).

In addition to the case of the Wistar vaccine testing, there are at least four other instances in which opponents of the OPV theory have claimed its refutation: the case of a Manchester sailor who apparently died of AIDS in 1959 (Basilico *et al.*, 1992), a molecular clock calculation of the date of the origin of AIDS

(Korber *et al.*, 2000), the analysis of a chimp SIV (Worobey *et al.*, 2004) and the discovery of a new chimp SIV (Keele *et al.*, 2006). However, proponents (especially Hooper) have shown how the new evidence is actually compatible with the OPV theory.<sup>6</sup> This is an example of the familiar process of scientists modifying theory to accommodate new findings. Opponents of the OPV theory, in claiming to have refuted it, have ignored the possibilities of modifying the theory and finding new evidence. Their tactic thus is selective application of the falsificationist principle.

In summary, opponents of the OPV theory have used two main interpretation techniques. First, they have assumed that the bushmeat theory is the default option, putting the onus of proof on OPV-theory proponents, despite producing little evidence for the bushmeat theory. Second, they have treated several challenges to the OPV theory—contrary evidence and theoretical findings—as definitive refutations, assuming OPV-theory proponents have no capacity for developing alternative explanations or finding new evidence.

### **Official Channels**

When people perceive something as unjust, they are often reassured when official bodies address the issue. Official processes give an appearance of justice, but in many cases there is little corresponding substance, as in the case of the Indonesian inquiries into the Dili massacre.

In science, peer review is a routine official channel, giving the appearance of fair treatment for contributions to scientific knowledge. In some cases, bias by editors and reviewers is given legitimate cover by the formalities of peer review (Horrobin, 1990). The anonymity of referees means it is hard to show evidence of alleged bias, as discussed earlier.

There are other official channels in science, for example deliberations of professional associations, expert panels and prize-giving committees. When allegations of scientific fraud are made, a committee may be established to investigate; if it is seen as sufficiently expert and independent, many people will see it as dealing authoritatively with the matter. When there are disputes over priority in scientific discovery, a prestigious award will be seen by many as an official stamp of approval for the recipient.

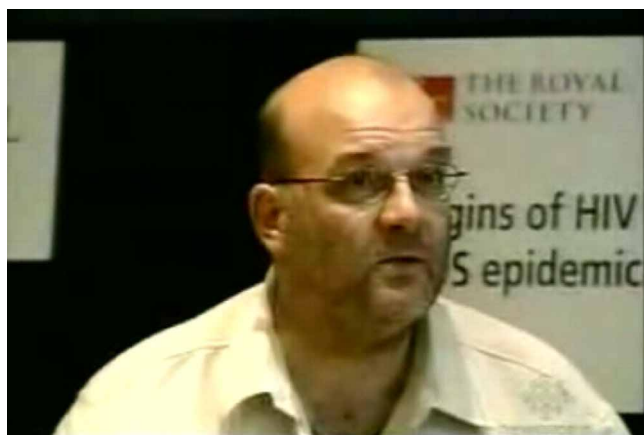
The peer review verdict on the OPV theory was almost entirely negative, with only a few supportive letters and articles appearing in peer-reviewed journals, but this verdict was not enough to banish the theory from consideration. Following publication of Curtis's *Rolling Stone* article in 1992, the Wistar Institute set up a committee of six prominent scientists—including one from the Wistar—to evaluate the OPV theory. The committee concluded that the theory was extremely unlikely to be correct, saying 'The most telling evidence is the case of the Manchester sailor who appears to have been infected with HIV-1 even before the poliovirus trials were begun in Congo' (Basilico *et al.*, 1992, p. 7). The Wistar

Committee report was just eight pages, with no references, and did not undergo peer review. Yet it was treated, in a story in *Science* (Anon, 1992), as a definitive refutation of the OPV theory. A few years later, independent testing of the sailor's tissue samples showed no evidence of HIV but did reveal cells from more than one person, raising serious doubts about the earlier testing (Zhu & Ho, 1995).

Through the rest of the 1990s, peer review and the Wistar report served to give the appearance that the OPV theory had been judged fairly and found wanting. The publication of *The River* in 1999 broke through this perception, giving much new evidence and argument. To probe the evidence posed by *The River*, the Royal Society of London held a 'discussion meeting' on the origin of AIDS a year later, partly at the behest of Hamilton. The meeting brought together Hooper, then the main proponent of the OPV theory (see Figure 1), leading opponents of the theory such as Koprowski, Korber and Hahn, and various other scientists doing relevant research (Hamilton died in March 2000, before the meeting was held).

The meeting was a dramatic affair, with heated interactions following some of the papers. Though portrayed by the Royal Society as an impartial assessment of the issues, in several ways the meeting was used as a tool to discredit the OPV theory (Martin, 2001b). The meeting was postponed by six months after several leading OPV-theory opponents, including Hahn, Korber, Koprowski and Stanley Plotkin, Koprowski's former deputy, threatened to withdraw unless changes were made to the schedule.

The meeting ran for two days in September 2000; strangely, the meeting's news conference was set for mid-afternoon on the *first* day. A late change of schedule inserted an announcement about the results of testing of Wistar polio vaccine samples just before the news conference. OPV-theory opponents and some



**Figure 1.** Edward Hooper at the September 2000 meeting of the Royal Society on the origin of AIDS. *Credit:* Edward Hooper, [http://www.aidsorigins.com/component/ooption,corn\\_easygallery/Itemid,75/](http://www.aidsorigins.com/component/ooption,corn_easygallery/Itemid,75/)



media representatives had been briefed about these findings, but not Hooper. At the meeting and news conference, the test results were treated as a definitive refutation of the OPV theory. At the same time, Hooper's dramatic announcement of evidence that chimp kidneys had been excised in Africa and sent to a vaccine-making lab was ignored.

The proceedings of the meeting were published the following year (Weiss & Wain-Hobson, 2001); opponents of OPV, led by Plotkin, were given the opportunity to write an additional rebuttal of Hooper's paper (Plotkin *et al.*, 2001) whereas Hooper was not given an equivalent opportunity to reply to other published papers. The Royal Society meeting gave the appearance of neutral expert evaluation of a scientific issue by an elite body while behind the scenes it was used to advance the cause of one particular view on the matter.

In 2001, a similar meeting was held by the Accademia Nazionale dei Lincei, the Italian counterpart of the Royal Society. It was more even-handed but received relatively little publicity.

In the letters by anti-OPV scientists to directors of film festivals, the authors state 'Two international scientific meetings have been held on this subject, where full presentations by the British journalist who invented the HIV–Polio idea were given, and the conclusion was reached that *no substantive evidence supported it*' (emphasis in the original). This is incorrect in several respects. The OPV theory was not invented by Hooper ('the British journalist'), though he has certainly done more than anyone to develop and advance it.<sup>7</sup> More importantly, the two meetings did not reach a conclusion: they were not consensus conferences, but rather meetings where papers were presented and discussed. Furthermore, Hooper at both meetings presented a large quantity of evidence to support the OPV theory (Hooper, 2001, 2003), though that does not mean the theory is correct. The film-festival letters illustrate the way OPV-theory opponents have sought to use the meetings as official endorsement for their viewpoint.

## **Intimidation**

The primary way in which OPV-theory proponents have been intimidated is through legal threats and actions. Defamation law is ostensibly about protecting reputations but in practice often is used to discourage free speech (Pring & Canan, 1996; Donson, 2000). Following publication of Curtis's article in *Rolling Stone*, Koprowski sued both Curtis and *Rolling Stone* for defamation (Anon, 1993a). The case never reached court: the matter was settled by *Rolling Stone* paying Koprowski a token one dollar and publishing a 'clarification'. This agreed statement by *Rolling Stone* stated that the OPV theory 'was one of several disputed and unproven theories', summarised the findings of the Wistar Committee, vouched for the safety of current polio vaccines and regretted 'any damage to Dr. Koprowski's reputation that may have been caused by the article' (Anon, 1993b). This 'clarification' did not assert that the OPV theory

was wrong, but this was the interpretation implied in a *Science* news story titled, ‘*Rolling Stone* rolls over for Koprowski’ (Anon, 1993c).

*Rolling Stone* by this stage reportedly had spent \$500,000 on the case; its willingness to settle appears to have been influenced by financial considerations. Yet the *Science* story did not highlight that statements in the ‘clarification’ were made under legal duress.

Although Curtis’s costs were covered by *Rolling Stone*, he did not join the magazine in the settlement and the case exacted a serious toll on him. He had to spend a large amount of time on the case; as a freelance journalist, this meant less time to earn an income. In the discovery phase of the case, he had to provide copies of his copious interview recordings, notes and other documents on the issue. Fortunately for Curtis, his *Rolling Stone* research was based entirely on public documents and recorded interviews. None of his individual sources for the story had requested anonymity, so he did not break a trust with any informants, but if the circumstances had been different—if, for example, Koprowski’s suit had included Curtis’s *Houston Post* stories and required surrendering documents about what he had learned *after* publishing the *Rolling Stone* story—Curtis feared that the compulsion to supply notes and names of sources might have forced him to either go to jail or identify his very few anonymous sources. In any event, Curtis’s capacity for further investigation of the issue was undermined, because he would have had to tell potential interviewees that anything they said to him might end up in the hands of Koprowski’s lawyers. Curtis had prepared a second article for *Rolling Stone*, but, following the legal action, the magazine declined to run it.

Koprowski’s suit thus had a major impact on the debate, prompting *Rolling Stone* to publish its ambiguous ‘clarification’, derailing publication of Curtis’s second article and removing Curtis as a major player in the subsequent debate. Furthermore, the suit—and another one by Koprowski against Associated Press over a news story about the theory—apparently discouraged other media from reporting the story, as there was a rapid decline in coverage.

Hooper and his publishers have received a number of demanding and threatening letters from Koprowski’s lawyers, and from Stanley Plotkin, a key collaborator of Koprowski. Hooper has resisted the demands and has not been sued. However, after initial print runs of *The River* sold out, neither Penguin, the British publisher, nor Little, Brown, the US publisher, has reprinted the book. A letter from Koprowski’s lawyers to Penguin may have played a role in the decision not to reprint the book.

Hooper reports an apparent instance of legal intimidation concerning the film *The Origins of Aids*:

In 2003, British lawyers representing the scientists who had developed and produced the Koprowski vaccine in the 1950s wrote a 63-page letter to Channel Four TV—one of the original financial backers of the film—which persuaded Channel Four not to broadcast the film in the UK.

Channel Four's legal team did not take up my offer to discuss the lawyers' letter with them, and to examine what I felt to be scientific flaws and misrepresentations contained therein (personal communication, 4 May 2009).

These examples illustrate the close connection between intimidation and cover-up.

## **Conclusion**

Opponents of the OPV theory have used a wide variety of techniques: they have blocked publication in peer-reviewed journals, delayed releasing polio vaccine samples for many years, disparaged the theory (mostly behind the scenes), put the onus of proof on OPV-theory proponents, claimed repeatedly that the OPV theory has been refuted, used an expert committee and scientific conferences to claim authoritative rejection of the theory, and used legal actions to discourage publications about the theory. These techniques fit within the five types of methods commonly used by perpetrators to reduce public outrage from a perceived injustice or norm violation.

One way to view this process is to say the OPV theory poses a threat to the image of medical research by attributing the origin of AIDS—a disease that has killed tens of millions of people—to medical research itself. It especially threatens the legacy of Koprowski and his associates who developed the vaccine in question. One response to this threat is to attack the OPV theory, but there is a risk: such an attack, if seen to transgress expectations for how science is carried out, might generate increased interest in and support for the theory. Therefore, according to the backfire model, it is to be expected that one or more of the five methods of inhibiting outrage will be used: cover-up, devaluation, reinterpretation, official channels and intimidation. In practice, all five methods are observed in this instance.

Applying the backfire framework to a scientific dispute reveals a subtlety not apparent in many other cases: each of the five methods of inhibition itself can be a source of outrage, independently of the original injustice. After the Dili massacre, the Indonesian military tried to prevent information escaping, for example by seeking to confiscate Max Stahl's videotapes. Censorship can itself be a source of outrage (Jansen & Martin, 2003)—it is a violation of the widely lauded principle of free expression—but in this case censorship was a minor concern compared to the massacre. Similarly, the Indonesian government's reinterpretation of the events as triggered by the actions of the East Timorese protesters—seen by informed observers as a transparent lie—could be a source of outrage, but again paled into insignificance compared to the massacre. In short, most means of inhibiting outrage were far less objectionable than the action in question.

In a scientific dispute, the techniques of engagement are themselves more likely to be a source of concern, because they are the means by which a theory is challenged and possibly rejected. One of the techniques, (re)interpretation, is a routine part of the disputes over ideas. If one side believes the interpretation has been

unfair, that claim is itself part of the interpretation struggle. Official channels, such as expert committees, are also a common part of science, convened on occasion to deal with a theory dispute. The process is standard, so critics have to argue there are flaws in the way the process was carried out.

Cover-up is a violation of the expectation of openness in science, but in practice many parts of science are not open. Anonymous peer review is widely accepted, so rejecting publications about a theory without public accountability is possible. Failing to release samples to test a theory is more problematical. The Wistar Institute, despite publicly offering in 1992 to release vaccine samples for testing, did not do so for nearly a decade, until publicity following publication of *The River* made its original position less tenable.

Public attacks on opposing scientists are a serious violation of expectations for behaviour in science, and can be counterproductive. Therefore it is not surprising that there are few instances from opponents of the OPV theory. However, behind-the-scenes criticisms are commonplace.

The use of intimidation in scientific disputes is widely considered to be improper: judgements are supposed to be made on the basis of facts and logic, not the exercise of power. Although there is considerable evidence of attacks on dissident scientists (Martin, 1999; Kuehn, 2004), most of this is hidden: cover-up and intimidation often work in conjunction. Koprowski's early legal actions were publicised and a possible source of outrage, but there was only a little open condemnation (Martin, 1993b; Curtis, 1995), possibly because the actions were targeted at journalists and media companies rather than scientists and scientific journals. Koprowski's more recent threats against book and journal publishers and television companies, described earlier, have been more covert.

Outside science, perpetrators of acts widely considered unjust—such as torture, or killing of peaceful protesters—are often able to avoid serious repercussions; typically, they use one or more of the five methods of reducing outrage, and this is sufficient to prevent or minimise backfire. This is because the perpetrators have more power: the power to hide actions, to assign labels to victims, to frame interpretations, to establish laws and hold formal inquiries, and to intimidate.

In science, a parallel process is possible. It is widely considered unfair to use double standards in evaluating scientific theories, but powerful supporters of a theory often can dismiss challenges without serious repercussions by using the same five methods of reducing outrage. Several of these methods are standard practice: anonymity in peer review, assumptions about the onus of proof, and expert panels and scientific conferences.

Often there is considerable agreement about what is unjust or improper, in principle, and the dispute is over the existence or meaning of particular events. Every government in the world condemns torture and denies any involvement in it; others, for example Amnesty International, say dozens of governments are involved in torture. In any particular case, there is no independent, neutral,

omniscient arbiter to say what actually happened. In the aftermath of the Dili massacre, the Indonesian government blamed the protesters for an incident in which 19 people died. Many people, though, were convinced by testimony and visual evidence that the protest was peaceful and Indonesian troops opened fire without warning, killing hundreds of people.

Similarly, in science there is often considerable agreement about what is involved in assessing theories fairly; disputes arise about particular cases. Opponents of the OPV theory say submissions have been evaluated fairly whereas supporters claim there has been bias. There is no neutral higher authority to assess claims of fairness or bias; higher authorities are themselves tools used in waging the struggle.

This framework highlights the powerful advantages held by supporters of dominant scientific theories. The treatment of challengers may be quite fair in terms of standard perceptions, but when the treatment might be seen as unfair, the methods of inhibiting outrage are powerful tools.

In summary, how can scientists attack a theory and get away with it? There are lots of ways of attacking, such as withholding evidence, blocking publications, demanding an excessive level of proof, making disparaging comments about ideas and individuals, publishing spurious refutations, ignoring evidence, not responding to arguments, denying research grants, threatening careers and taking legal action. The trouble with most of these methods is that they seem to be unfair: they violate common expectations of how science is supposed to work.

So how do scientists get away with attacks? Partly by hiding them, reinterpreting the attacks as normal behaviour, and by using expert forums such as panels, conferences and journal editorials to give the stamp of authority to rejection of the theory. And partly through the effects of the attack itself: disparaging comments lower the credibility of targets and intimidation scares many into silence.

Effective resistance requires countering the attacks, for example collecting evidence, seeking alternative avenues for publication, emphasising key arguments and refusing to be intimidated. There are no guarantees: even the best tactics may be inadequate if the other side has overwhelming resources. Furthermore, in many cases, a fair-minded assessment of a theory, in the absence of attacks, would still be negative: just because you're attacked unfairly doesn't mean your theory is better.

In many public policy disputes, scientific theories are attacked as part of a wider struggle involving politics, economics and ethics. In such situations, it is naive to assume that scientific theories will be evaluated neutrally and fairly. Being prepared means that the attackers won't always get away with it.

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## Notes

- <sup>1</sup>See <http://www.bmartin.cc/dissent/documents/AIDS/> for key publications about the theory.
- <sup>2</sup>The paperback edition, with a long new postscript, was published the following year (Hooper, 2000). Hooper subsequently set up a website: <http://www.aidsorigins.com/>.
- <sup>3</sup>I have in my possession copies of this letter signed by Beatrice Hahn, Bette Korber, John Moore, Stanley Plotkin, Mark Wainberg, Robin A. Weiss and Steven Wolinsky. Each letter is individually signed but the text is virtually identical: the letters say 'The signers of this letter are all scientists involved in public health or more specifically the fight against AIDS'.
- <sup>4</sup>At the Royal Society meeting, Koprowski (2000) made available a press release stating 'we have been left with the task of controlling damage done by *The River*, as a result of which people are questioning the vaccination of children'. Hooper (2004a) later issued a detailed rebuttal.
- <sup>5</sup>OPV-theory opponents seem to imply that the theory should be rejected, or ignored, if it leads to undesirable social consequences. This raises an intriguing set of issues, not explored here.
- <sup>6</sup>The case of the Manchester sailor is discussed later. On the molecular clock see Hooper (2003). On the two chimp SIV claims, see Hooper (2004b) and Hooper (2006a, 2006b).
- <sup>7</sup>To say that Hooper 'invented' rather than 'developed' the OPV theory might seem to be a way of denigrating both Hooper and the theory.

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