10 Imagining future biothreats

The role of popular culture

Filippa Lentzos, Jean-Baptiste Gouyon and Brian Balmer

In thinking about the future, NATO claims to be taking a leaf out of Google co-founder Sergey Brin's book. Brin's approach to technology investment is that 'If what you're doing is not seen by some people as science fiction, it's probably not transformative enough' (Jha 2013). Following Brin's lead, Allied Command Transformation – the US-based strategic command at the head of NATO's military command structure – has turned to science fiction to help the organization advance its thinking about transformative technologies and future threats.

It commissioned a series of short stories from a group of futurist authors, asking them to explore and imagine how technology and trends could affect future operations. The authors were given a profile of the future developed from NATO's futures work, but were otherwise 'unbounded by military strictures or the subliminal requirement to be "realistic"' (Allied Command Transformation 2016: 9). The resulting anthology, *Visions of Warfare 2036*, was published in November 2016, with the aim 'to incite inventive thinking and discussion about future possibilities and to add to the toolbox that the Alliance military and others can leverage to imagine and contemplate how NATO will undertake operations in the coming decades' (Allied Command Transformation 2016: 9–10). In his introduction to the unprecedented anthology, the Director for NATO capability development at Allied Command Transformation, Lieutenant General Jeff Lofgren, writes:

> Many inventions and innovations were described in stories many years before they became a reality. Advanced submarines, flying to the moon, flip phones, iPads and the Internet itself were foretold decades before the underlying scientific challenges were solved. That futurist literature informs or inspires product design has become an established practice.
>
> (Allied Command Transformation 2016: 9)

In this chapter, we explore the wider and more informal role of futurist storytelling, or as NATO calls it 'futurist prototyping', in relation to biological weapons.

Biological weapons are, of course, prohibited. Their use in war was banned in 1925 under the *Protocol for the Prohibition of the Use in War of Asphyxiating,*

Poisonous or other Gases, and of Bacteriological Methods of Warfare (usually shortened to the Geneva Protocol); their development, production and stockpiling was banned under the 1972 *Biological Weapons Convention* (BWC). Yet concerns about these weapons have endured, and continue to escalate. A major source of growing concern about future biological weapons threats is military 'overmatch' ambitions (Lentzos 2018). In NATO countries, efforts to stay ahead of adversaries often rely heavily on investments in technological innovation and, today, a considerable part of that investment goes into the biological sciences. For instance, at DARPA (Defense Advanced Research Projects Agency), the US military's research wing – the goal to 'harness biology as technology' is one of four main areas of focus for its strategic investments.

Military investments in biology are coinciding with technical advances that have increasing potential for misuse (IAP 2015; Caves and Carus 2014). For instance, developments in microbiological, immunological and epidemiological research have been identified as potentially leading to the production of more 'useful' biological weapons: dangerous pathogens with increased virulence, altered host range, increased transmissibility, or greater resistance to therapeutic interventions (Lentzos 2017). Gene editing and engineering technologies have been identified as another area of concern, where developments could enable dangerous pathogens to be constructed from scratch in the lab, eradicated pathogens to be reconstituted, or entirely novel pathogens to be designed (Ben Ouagrham-Gormley and Vogel 2016; Koblentz 2017). Moving beyond pathogens, DNA origami, focused on folding DNA into nanoscale shapes, designed to perform specific mechanical functions or biological interactions, could potentially be used to programme nanorobots to release damaging payloads inside human bodies (Lentzos and Invernizzi 2018); and developments in neurobiological research could potentially be misused to alter people's emotions or memories, covertly implant ideas or cause cognitive shifts (Bruner and Lentzos, 2017).

Added to these technical advances is a convergence of contextual factors that could also contribute to lower barriers to biological weapons development and use (Lentzos 2017; Caves and Carus 2014). Geopolitically, an increasingly multipolar world is emerging, one in which rising powers view human rights, justice, transparency and the use of force differently. In this new environment, the treaties prohibiting biological weapons – the Geneva Protocol and the BWC – may be eroded. The nature of conflict and warfare is also rapidly evolving, and the character of military challenges confronting states is changing (Kaldor 2007, 2013). Under these conditions, with uncertainty, insecurity and complexity growing, some states may develop novel bioweapons for covert use in small-scale operations. States may even consider developing novel biological weapons for overt use against unprepared adversaries when they become involved in conflicts so serious that the advantages of using banned biological weapons are perceived to outweigh the political costs and military risks of resorting to proscribed weapons.

Efforts to characterize the threat of potential future biological weapons are politically more pertinent than ever. Yet, how can reliable predictions be made?

In this chapter, we discuss some of the difficulties inherent in making realistic assessments of the threat from future biological weapons, and we explore an element of these assessments that is understudied but significant: imagination and popular culture. We first describe the barriers and difficulties in making precise bioweapons threat assessments. We then make a theoretical case for why science fiction and anticipatory knowledge production are interlinked: Science fiction texts, and popular culture more broadly, are part of larger processes of knowledge diffusion and 'sense making'. Our cognitive concepts and the ordering frameworks we apply to the world are constituted and produced through the countless narratives and stories people invent and pass on.

Following Nexon and Neumann, we hold that art and popular culture should not only 'be treated as evidence about dominant norms, ideas, identities, or beliefs in a particular state, society or region' (Nexon and Neuman 2006: 13), but that culture can also co-constitute political actors, problems, values, representations and threat assessments. 'Art is the fountainhead from which political discourse, beliefs about politics, and consequent actions ultimately spring', Edelmann similarly writes.

> [It] should be recognized as a major and integral part of the transaction that engenders political behaviour. […] Works of art generate the ideas about leadership bravery, cowardice, altruism, dangers, authority, and fantasies about the future that people typically assume to be reflections of their own observations and reasoning.
>
> (Edelman 1995: 2–3)

As such, we use pop culture as a 'lens' that might provide insight into understanding how different groups 'see' biological weapons and how science fiction has a constitutive effect on biological threat assessments. We will illustrate our argument by introducing some of the most prominent examples from the bioweapons sci-fi genre. The chapter ends with an outlook on some of the key research questions that arise in this area.

Assessing future bioweapons threats

As barriers to biological weapons development and use decrease, identifying potential future biological weapons threats becomes more pressing. Yet, how, politically, do we start to conceive of these threats? What guides us in our thinking about the ways in which life science technology can be misused? What tools and information can reliably be drawn on? From where do we take our inspiration?

We know, of course, a great deal about natural outbreaks of disease; how they unfold, what their effects are, and how they impact communities more broadly. And we've had some experience of recent emerging disease outbreaks – SARS, H1N1, MERS, Ebola, Zika to name a few. But none of these are deliberate outbreaks. The historic record of deliberately introduced disease

outbreaks is very limited. There has only been a handful of incidents where amateurs, cults and other non-state actors have attempted to deliberately spread pathogens (Carus 2002), and there has been no documented state use of biological weapons – with the exception of secret, experimental use by Japan against civilians in rural Manchuria in China in the 1930s (Guillemin 2017) and covert attempts by Germany to use biological agents against livestock in World War I (Wheelis 1999).

There are examples of the sorts of biological weapons that were developed in some countries, such as pathogens on missiles, or in cluster bombs, spray tanks and aerosol generators, even pathogen-contaminated food (Lentzos 2016; Wheelis, Rózsa and Dando 2006). There is no comprehensive list, however, and the goals, motivations and ambitions behind the weapons are very different and often unclear, spanning the range from deterrence, intimidation, tactical military use, covert warfare, sabotage, to state-sponsored terrorism and assassination (Tucker 2000). There is not even a generally accepted list of past – or contemporary – states with biological weapons programmes from which to extrapolate into the future. Part of the problem with developing such a list is conceptual (Carus 2017). What does it mean to assert that a country has a biological weapons programme? As Seth Carus (2017: 130) has noted:

> Does a country have a program when it decides to acquire biological weapons? Or must it have some activity underway? If so, is a research activity sufficient evidence of a BW program, or must the country have progressed to the development of delivery systems? What would it mean to say that a country has a delivery capability?

Another major part of the problem is secrecy. Past biological warfare programmes were cloaked in extreme secrecy, concealed in laboratories at military sites often not listed on ordinary maps; with biological agents and projects designed to weaponize them assigned special code names and exceptionally high classification categories, and bioweaponeers sworn to secrecy and placed under constant surveillance. Likewise, any field testing of agents was undertaken with elaborate procedures for maintaining secrecy. While traces can be found in some official records, as well as through qualitative research, enabling parts of weapon programme histories to be pieced together (e.g. Gould 2005; Balmer 2001; Guillemin 1999), much of the documentation and other evidence of past programmes has been destroyed or remains classified.

Today, in stark contrast to nuclear weapons programmes, there are no countries that admit to having an offensive biological weapons programme. While government assessments of biological threats from sub-state actors – on the rise since the breakup of the Soviet Union in the early 1990s, and even more so following 9/11 and the anthrax attacks in the US a decade later (Wright 2007; Guillemin 2005; Vogel 2016) – are readily available, publicly available government assessments of biological weapon threats to national security from states are generally rare. The exception is the United States, whose State Department

annually reports on its compliance concerns with arms control, nonproliferation and disarmament treaties. The most recent report expressed concern that the Russian Federation has not 'satisfactorily documented whether [its inherited Soviet offensive] program was completely destroyed or diverted to peaceful purposes' but it is scant on additional details (US State Department 2018). Reports in previous years have expressed concerns about a number of other countries, peaking at 13 following 9/11 and the anthrax letters; these have been equally scant on detail. A small number of states (e.g. Israel) have not signed up to the BWC, while others (such as Syria and Egypt for example) have not ratified it.

Some conclude that 'open source information cannot unambiguously answer the question whether or not a state has offensive BCW [biological and chemical weapons] programmes' (Bucht *et al*. 2003: 97). Yet, there are challenges even for those privy to classified information (Vogel 2008, 2013; Nolan 2013). Vogel, for instance, demonstrates how the 'anticipatory frame' that CIA analysts used in their incorrect assessment of Iraq's biological weapons programme before the US invasion of Iraq in 2003 fixated the analysts on particular 'technical' pieces of information rather than integrating the more complex qualitative social, political and economic dynamics shaping Iraq's biological weapons development: 'factors which ultimately proved to be decisive' (Vogel 2008: 571). And it is not only in Iraq that the intelligence community got the biological weapons threat wrong. The size, scope and sophistication of the Soviet biological weapons programme took the US intelligence community completely by surprise when it began to be uncovered at the end of the Cold War, and the intelligence community also had to reevaluate assessments it made in the 1990s and early 2000s that Libya and Cuba had active BW programmes, retroactively concluding that its earlier judgements were incorrect (Carus 2017). As one senior official in the CIA's Counterproliferation Division reflected: 'We don't know more about the biological weapons threat than we did five years ago, and five years from now we will know even less' (Commission on the Intelligence Capabilities of the United States Regarding Weapons of Mass Destruction 2005).

Clearly, there are limited tools and data sets that can reliably be drawn on in evaluating future biological threats. This opens the assessment space to greater influence from other drivers and shapers. Some of these are direct and obvious, for instance, terrorism events like the World Trade Center and Oklahoma City bombings, the Aum Shinrikyo chemical attacks on the Tokyo underground, 9/11 and the subsequent anthrax letters; geopolitical events like the collapse of the Soviet Union, the revelations of defectors and informers, and the exposure of its Biopreparat biowarfare research organization; and particular scientific experiments, such as making mousepox more deadly, making bird flu transmissible between mammals, synthesizing poliovirus or horsepox from scratch, or reconstructing the extinct 1918 flu virus.

Other drivers and shapers are less 'trigger-like' and act more subtly: cumulative advances in different scientific fields; experiences of disease and pandemics like SARS, influenza, Ebola, MERS and Zika that provide clues as to what a

biological weapons attacks might be like or how to ascribe the cause to natural or deliberate factors (e.g. Martin *et al*. 2008); and strong personalities keeping the issues visible – scientists, weaponeers, politicians and security advisors alike.

There are also some drivers and shapers of biological threat assessments that have so far largely gone unrecognized in the scholarly and policy literature. We are interested in one of these, namely fictional imaginaries, which we suspect play a significant role in inspiring visions of future biological weapons. There are already a number of anecdotes circulating of science fiction affecting political conceptions. A good example comes from the Clinton administration in the 1990s. Investigative journalists with the *Times* and *The New York Times* have highlighted the role of fiction in supporting President Clinton think through future biological weapons threats. Amongst other things, they describe a meeting where J. Craig Venter, the pioneering synthetic biologist, discusses the misuse potential of synthetic biology with President Clinton. Venter had been part of the effort to map the smallpox virus and Clinton, they write, 'asked if smallpox could be spliced with another bug to make it more harmful. Venter replied that it could and that a new novel – *The Cobra Event* […] presented just such a scenario' (Miller *et al*. 2001: 224). Clinton apparently took a special interest in biological weapons, and he read widely on the topic:

> He devoured histories, newspaper and magazine articles, and especially fiction. Tom Clancy's *Rainbow Six*, a thriller about a counterterrorist team's efforts to prevent Armageddon, made a big impression. Another favourite was a Patricia Cornwell novel that focused on a female medical examiner's battle against a shadowy figure intent on using mutant smallpox for mass murder. But nothing caught the president's attention as much as *The Cobra Event*, the novel Venter had recommended and that Clinton read in early 1998. It depicted a mad scientist's determination to thin the world's population by infecting New York City with a designer pathogen. By combining smallpox, a virus similar to that of the common cold, and an insect virus that destroys nerves, the scientist invented an ideal doomsday germ – a 'brainpox' that spread quickly and melted the brain.
>
> (Miller *et al*. 2001: 224)

We are interested in understanding more systematically how science fiction impacts political thinking and the way in which it shapes how biological weapons are 'seen', not just by those at the very top, but by political stakeholders broadly understood, including civil servants, military officers, intelligence analysts, bioweapon expert, disarmament diplomats, activists and campaigners. In the following sections, we will first outline the theoretical case for examining how science fiction and anticipatory knowledge production are co-constituted and then provide a range of examples from the bioweapons genre to illustrate our claims.

Science fiction and anticipatory knowledge production

Lieutenant General Lofgren, the NATO Director for capability development, noted that futurist literature can inspire product design. This, of course, has been observed by a number of scholars too. Sheila Jasanoff, for instance, opens the introduction to her edited volume *Dreamscapes of Modernity* with the observation that 'Technological innovation often follows on the heels of science fiction, lagging authorial imagination by decades or longer' (Jasanoff 2015: 1). She highlights, among other examples, Mary Shelley's Frankenstein and the production of new life forms in biological labs nearly a century and a half later; Jules Verne's Nautilus heralding submarines before they became a reality many decades later; and Aldous Huxley's assembly-line of artificial human reproduction to serve state purposes dreamed up in the early 1930s and which is now starting to become a technical, if not moral, feasibility.

Science fiction stories can be meaning-making devices that bring certain worlds into existence whilst pretending only to describe them (White 1987; Curtis 1994). Looking at the specific case of movie portrayals of not yet existing technologies, what he calls 'diegetic prototypes', science communication scholar David Kirby remarks that cinematic representations of yet-to-be technologies 'can lead to real-world technological development' (Kirby 2010: 43). When these technologies are embedded within a narrative frame as part of the protagonists' everyday life, diegetic prototypes demonstrate to audiences these artefacts' necessity and viability. Because one social function of public expositions of science and technology is to create markets for innovations (Thorpe and Gregory 2010), by generating positive social expectations, diegetic prototypes can prompt corporate action and participate in turning fictional devices into actual artefacts. An example here is the gesture-based computer interface featured in Steven Spielberg's 2001 *Minority Report*. The film vernacularized a technology which has since become ubiquitous, notably as a key feature of smartphones. There are numerous such examples that can be pointed to, as testified by the consulting company, *SciFutures*, that NATO employed to create its *Visions of Warfare 2036* anthology and which also makes money out of creating customized sci-fi narratives for the likes of corporate giants Visa, Ford, Pepsi and Samsung (Romeo 2017).

Typically, however, science fiction writers distance themselves from straightforward cause–effect relations. For instance, Arthur C. Clarke, who created 'the scheming, lip-reading computer Hal thirty years before IBM programmers developed Deep Blue to beat chess master Gary Kasparov at his own game' (Jasanoff 2015: 1), has noted that:

> […] contrary to general belief – prediction is not the main purpose of science fiction writers; few, if any, have ever claimed 'this is how it will be.' Most of them are concerned with the play of ideas and the expiration of normal concepts in science and discovery. 'What if….?' is the thought underlying all writing in this field. What if man could become invisible?

> What if we could travel into the future? What if there is intelligent life elsewhere in the Universe? These are the initial grains around which the writer secretes his modest pearl. No one is more surprised than he is, if it turns out that he has indeed forecast the pattern of future.
>
> (Arthur C. Clarke (1977) cited in Erikson 2016: 194–5)

Science fiction stories are generally not meant to be predictions, estimates of future trends, nor blueprints for technological designs. They are explorative narratives about alternate, technologically inspired, worlds that are made up. Yet there are aspects of science fiction that ring true:

> [...] true in the sense of careful, thoughtful representations of what it might be like to live in the kind of world we might get in the future; true in the deeper sense of reflecting enduring realities of human existence, meaning, and identity; true in the sense of illustrating fundamental moral dilemmas faced by individuals and communities when confronted by new and emerging technologies, and the struggles to grapple meaningfully with those dilemmas in the only ways humans know how.
>
> (Miller and Bennett 2008: 600)

Science fiction thus has the potential, argue Miller and Bennett (2008), to be more than just story-telling; science fiction can present inquiries into the human dimensions of technological futures, they enable 'societies very different from our own to come alive' (Miller and Bennett 2008: 600). It is often the social aspects, not the technological ones, that drive futurist stories. As Jasanoff reflects about the interplay of social and material innovation in her *Dreamscapes of Modernity* introduction:

> Shelley's lab-generated monster turns murderous because he is excluded from society by his abnormal birth, and hence is denied the blessings of companionship and social life enjoyed by his creator. Jules Verne's Nemo, a dispossessed Indian prince driven by hatred of the British colonialists who exploited his land and destroyed his family, seeks freedom and scientific enlightenment in the ocean depths. Biopower runs amok in Aldous Huxley's imagined world, overwhelming human dignity and autonomy in the name of collective needs under authoritarian rule.
>
> (Jasanoff 2015: 1)

Bringing social thickness and complexity to considerations of technological developments has been a central aim of the field of science and technology studies (STS). Covering the history, philosophy and social studies of science, STS explores the co-constitutive processes between science and socio-political order, and has developed an interest in science fiction as a manifestation of science in popular culture. As a field of scholarship interested in understanding the relationship societies and cultures maintain with science

and technology, STS has tended to approach science fiction as an index of this relationship.

STS scholars assert that because literary creations are not created in a vacuum, the socio-technical imaginaries to be found in science fiction novels can be taken as commentaries, on their authors' part, on the state of science and technology at a given time and place (Sleigh, 2011).

> Science fiction offers a unique approach to thinking longer term about technology: one grounded in narratives that are people-centric, future-oriented, and focused on non-linear dynamics across the interaction of multiple technologies, value-laden images of future societies, questions of meaning and identity, and enduring symbols and problem framings.
>
> (Miller and Bennett 2008: 597)

As such, these texts are not only useful as sources for a kind of historical sociology of science, but also for mapping 'collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology' (Jasanoff 2015: 4).

H. G. Wells' *The Island of Dr Moreau* (1896) provides a useful example. This short novel tells the story of the gruesome experiments that a scientist, exiled on a remote island and thus freed from the oversight of society, conducts on animals. The novel appeared in London shortly after the British Institute for Preventive Medicine was opened. In the early 1890s, this institute acted as a magnet for opponents to vivisection, at the time one of the most controversial techniques employed in medical research. *The Island of Dr Moreau* can be analysed as Wells reflecting on the cultural implications of this research method and on laboratory science more broadly. The novel, Martin Willis (2006) argues, presents readers with Wells' views on the potential dangers of leaving scientists' activity unchecked. The fictional account makes the case for the necessity of the social body to exert scrutiny on what is happening in laboratories at a time when they were rising as the core institution of professional science (Willis 2006).

The eponymous 1996 film adaptation of Wells' novel by John Frankenheimer can similarly be interpreted as an attempt to engage spectators in a reflection on the contemporaneous affordances of the life sciences. Frankenheimer's infamous adaptation features Marlon Brando, in one of his last appearances, as Dr Moreau. Just like his nineteenth-century counterpart, this Dr Moreau is concerned with perfecting the human race. Here again, it involves producing human-animal chimeras. But in the late twentieth century, genetic engineering has displaced vivisection as the main tool in the hand of the mad scientist. 'I have seen the devil, in my microscope. And I have changed him. … I have cut him into pieces. The devil … I found, is nothing more than a tiresome collection of genes', Brando-Moreau grandiosely intones in front of his dumbfounded antagonist Thewlis-Douglas.

Just as the 1890s were the decade of vivisection, so the 1990s were the decade of the gene. The year 1990 saw the American Department of Energy, the agency responsible for developing the US atomic bomb, pair with the American National Health Institute to launch the Human Genome Project. This endeavour to decrypt the entire complement of human DNA was met with expressions of worries and fear. For instance, an article in the British broadsheet the *Guardian* titled 'The Frankenstein Factor' warned of 'the sinister shadow of gene bending and social control' (Tyler and Kilmowski 1991). Another, later piece, explained transgenics as the 'manipulation and exchange of DNA', a science touching 'the core of our existence, able to blur the boundaries between animal, vegetal and mineral'. The article also warned that 'gene-pharms' applied transgenics to create 'hormonally mixed animals and plants chimeras which could appear on supermarket shelves' (Kohn 1994). The 1996 adaptation of *The Island of Dr Moreau*, with its gallery of monstrous chimeras – animals given human appearance through genetic manipulation – is thus a cautionary tale against the horrors of gene tinkering, of the kind the Human Genome Project helped make imaginable.

As these examples show, science fiction novels and films are virtual spaces where moral questions related to current scientific innovations can be debated. They are spaces for moral thought experiments (Gil 2018), questioning the potential consequences of pushing this or that innovation to the extreme. Science fiction can also prompt questions about scientists as well as science. Haynes, for example, has shown how the representation of scientists in film shifted over the twentieth century from the 'mad' scientist to the 'amoral' scientist (Haynes 1994). This resonates with historical accounts that show how twentieth-century scientists, such as Robert Oppenheimer, struggled with the tension between being, on the one hand, a scientist with an obligation to comment on the ethics of his research and, on the other, being a mere technician of the state with a moral responsibility to defer such judgements to wider society (Thorpe 2004). Fictional texts thus highlight that there is more to truth than factuality. Beliefs about science's truth-claims are decided also on moral grounds: Fictional texts ask whether discoveries, methods of investigation, or innovations are useful, meaningful and even desirable to our human existence (Sleigh 2011). Sociologists Mikael Hård and Andrew Jamison (2005: 161) write:

> Popular science fiction or, perhaps more correctly, technofiction movies are important barometers that often highlight contemporary problems and reflect current public concerns. They can be regarded as sensitizing instruments that play an important role in the process of cultural appropriation.

The argument of course extends to the study of world politics, as Nexon and Neumann (2006: 6) observe: 'If culture profoundly affects politics, then we cannot neglect popular culture, since it is within popular culture that morality is shaped, identities are produced and transformed, and effective analogies and narratives are constructed and altered.'

Science fiction in popular culture, like other instances of the public exposition of science, makes technology and science part of audiences' lived experience. This can, as mentioned, help create markets for prospective technologies. But novels and films can also be cautionary tales. They can function as interventions, by their authors, in the debates surrounding potential uses and applications of ongoing scientific and technological developments. For audiences, to consume these texts can be a means of participating in these debates (Miller and Bennet 2008).

Science fiction, then, is not just a 'window' or 'passive mirror' onto an already preexisting world. Representations 'play a crucial role in constituting the social and political world' (Nexon and Neumann 2006: 6). They are 'part of the processes of world politics themselves: they are implicated in producing and reproducing the phenomena that [some approaches] assume they merely reflect' (Weldes 2003: 12). Similarly, in terms of technological innovation, science fiction literature and cinema participate in the production of scientific knowledge, technological development and the social debates that go alongside it.

This participation means that the firm division between the worlds of fact and fiction – which makes it easy to dismiss popular culture in 'serious' debates about threat prediction or arms control – becomes problematic. In this vein, historian of science, Jon Turney, in his book *Frankenstein's Footsteps* argued that from Mary Shelley onwards, public debates about the ethics of emerging life sciences have been shaped as much by scientific developments as by images and events in science fiction (Turney 2000). In an analysis of press and parliamentary debate transcripts of debates over the desirability of embryo research, Michael Mulkay showed how both protagonists and antagonists in the debate drew on fictional images in articulating their case (Mulkay 1996). One might expect critics of embryo research to use negative images from science fiction to describe scientists, but Mulkay showed that scientists defending their work also drew on negative images (Frankenstein) to distance their work from the fictitious character.

More recently, Priscilla Wald's book, *Contagious*, argues that 'the repetition of particular characters, images and storylines' during real-world disease outbreaks (e.g. Patient Zero, super-spreaders, tenacious microbes at war, etc.) has real consequences for how we respond to those outbreaks (Wald 2008). She documents a gradual change in the language through which the media depicted viral contagion and the changing Cold War world that suggests a conceptual exchange between the rapidly developing field of virology and Cold War Politics. Wald is worth quoting at length:

> As viruses became increasingly sinister and wily, sneaking into cells and assuming control of their mechanisms, external agents, such as Communists, became viral, threatening to corrupt the dissemination of information as they infiltrated the nerve center of the state, the exchange crystallized value and often conflicting anxieties about the changes of the post-war world. The new affiliations that came with political realignments brought

> the need for new stories of group origins and the triumph of human values shaped in the crucible of possible devastation: the histories and mythologies that accompany profound social change. The insights of virology were central to those stories, as the vocabulary that permeated the newspapers and science journals of the period found extended expressions in the plot of novels and films. Those works dramatized the new scientific concepts and, like the media, they acted as a kind of reservoir host – to borrow a metaphor from science – in which scientific and political theories recombined, informing the mythology of the new age.
>
> (Wald 2008: 159)

Moreover, in their study on the Cold War press coverage of the BWC negotiating period, Balmer *et al*. (2016) point to another noteworthy aspect of the culture–science link: Since all biological weapons research programmes during the Cold War were cloaked in secrecy, 'fictional accounts of disease as a weapon of war formed a more accessible source of imagery and speculation about what constituted biological weapons' (Balmer *et al*. 2016: 80). In their subsequent analysis of a corpus of UK and US newspaper articles written about biological warfare during the BWC negotiating period (the newspapers spanned 1967–75), they identify two narratives, apparently contradictory, used by journalists writing about the nature of biological weapons. On the one hand, biological weapons were portrayed as morally offensive, yet highly effective and militarily attractive. Yet, interwoven with this discourse was a second register, which painted a picture of biological weapons as ineffective, unpredictable and of questionable value for the military.

In short, studies of the interaction of popular culture and science, like Turney's, Mukay's, Wald's and Balmer's, demonstrate a lively two-way communication between fiction and on-going real-world debates and events. In the remainder of this chapter, we will illustrate this interplay by introducing some of the most prominent examples from the bioweapons sci-fi genre.

Bioweapons sci-fi

While a niche interest, there is still a reasonable amount of science fiction dealing with biological weapons and the deliberate introduction of disease. An early fictional portrayal is Robert and Fanny Stevenson's *The Dynamiter* published in 1885, in which an anarchist narrator suggests the possibility of contaminating the sewage systems of British cities with typhoid bacteria. A contemporaneous work, along a very similar theme, is H. G. Wells' *The Stolen Bacillus*. The short story, published in 1894, describes the failed attempt of an anarchist to steal cholera bacteria to poison London's water supply and cause an epidemic. Commenting on the work, Costa and Baños note that Wells' story has contemporary resonance because it raises the issue of how murderous acts by some groups – 'anarchists in the past, radical Muslims in the present' – might hamper our attempts to comprehend their motivations and world-view

(Costa and Baños 2016). Other notable early works are Robert Potter's *The Germ Growers* (1892) in which alien invaders try to wipe out humans using biological warfare, Jack London's *Yah! Yah! Yah!* (1909) in which a punitive European expedition to a South Pacific island deliberately exposes the Polynesian population to the measles virus, and Jack London's *The Unparalleled Invasion* (1910) in which Western nations wipe out all of China with a biological attack.

There is continual interest in bioweapons themes by science fiction writers during the Cold War. At the start of the space race, as the US announced its intention to launch a satellite into orbit, Jack Finney's *The Body Snatchers*, published in 1955, imagined germs from space drifting to Earth and invading a California town, replacing sleeping people with perfect physical duplicates grown from plantlike pods while their human victims turn to dust. In John Wyndham's *The Day of the Triffids* (1951), government scientists arm orbiting satellites with virulent organisms. The germs in space theme reappears in Michael Crichton's popular novel *The Andromeda Strain*, published at the peak of the space race, in 1969, when the US landed the first humans on the Moon with Apollo 11. Crichton's novel features a military space mission to gather pathogens for biological warfare. Mysterious microbes are then brought back to Earth on a space probe spurring a deadly outbreak that threatens human extinction. Similar apocalyptic themes comprise a number of novels, such as D. G. Compton's *Quality of Mercy* (1965), which portrays biological weapons as a means to combat overpopulation, and James Tiptree Jr's *The Last Flight of Dr. Ain* (1969), featuring a scientist travelling the world and releasing a virus targeted to eliminate humanity before it can destroy all life on Earth via climate change. In Frank Herbert's *The White Plague* (1982), a vengeful molecular biologist creates an artificial plague that is carried by men but only kills women. The scientist releases the disease in select countries, then holds the governments of the world hostage to his demands lest he release more plagues. Crossing into the horror genre, James Tiptree Jr's *The Screwfly Solution* (1977) imagines a disease that turns the human sex drive into a drive to kill, and Stephen King's *The Stand* (1978) narrates the accidental release of a weaponized strain of influenza from a remote US army base.

The post-Cold War period, with its rise of bioterrorism and rogue nations, as well as advances in genetic modification techniques, saw a string of novels featuring deliberate disease introductions, often through genetically engineered viruses. Perhaps best-known is Richard Preston's *The Cobra Event* (1998) – the novel that had grabbed Clinton's attention – with its 'Cobra' chimera of smallpox and flu virus forming the basis of a bioterrorism attack. Tom Clancy's *Rainbow Six* (1998), another Clinton favourite, featured an elite multinational counter-terrorist unit, 'Rainbow', which foils a radical eco-terrorist plan to carry out a sophisticated bioweapon attack with a mutated form of Ebola to infect Olympic athletes and spectators, and eventually wipe out the human race. *Executive Orders* (1996), an earlier Clancy novel, portrays an attempt by Iran to use a strain of airborne Ebola virus to infect and devastate the US population. In

other scenarios, Robin Cook's *Contagion* (1995) presented a mysterious deadly outbreak at a New York hospital which turns out to be spread by sabotage; Cook's later novel *Vector* (1999) saw a bioterrorist attack in the US using anthrax spores and botulinum toxin, and Chuck Hogan's *The Blood Artists* (1998) saw a deadly virus first appearing in the Congo resurface two years later in the US.

Films have also proved a popular medium for fictional portrayals of biological weapons. The novels, *Invasion of the Body Snatchers* and *The Andromeda Strain*, were both made into movies. John Sturges' 1965 film *The Satan Bug* portrayed a madman stealing a recently developed virus (the 'Satan Bug') from a secret bioweapons lab in the California desert which could wipe out the Earth's population in months. In the James Bond spy film *On Her Majesty's Secret Service* (1969), women were brainwashed by the villain to disseminate biological warfare agents throughout the world. Boris Sagal's *The Omega Man* (1971) saw biological warfare between China and Russia kill most of the world's population.

Two blockbusters in the 1990s stand out. Terry Gilliam's *Twelve Monkeys* (1995) presented a deadly virus that wipes out almost all of humanity, forcing remaining survivors to live underground. A mysterious terrorist group, known as the Army of the Twelve Monkeys, is believed to be behind the virus, but it turns out to have been released by a disgruntled scientist. In Wolfgang Peterson's *Outbreak* (1995), a highly infectious, deadly virus is transported to the US via an African monkey host and people start dying. The US Army Medical Research Institute for Infections Diseases and the CDC, headed by an ex-husband and his former wife, rush to stop its deadly spread.

The 2000s saw *Mission Impossible 2* (2000) in which a secret agent is sent to Sydney to find and destroy a genetically modified disease called 'Chimera' before a gang of international terrorists, who have already managed to steal the cure, get to it and can complete their grand plan of infecting the whole world. Danny Boyle's *28 Days Later* (2002) narrates how a deadly, modified 'rage' virus is accidentally released and leads to a breakdown of society. Steven Soderbergh's *Contagion* (2011), coming in the wake of the SARS and H1N1 outbreaks, presents a natural virus outbreak, spread from bats via pigs to humans and which affects victims' brain and central nervous system. Matthew Vaughn's *Kingsman: The Secret Service* (2014) turned its focus away from disease-causing to behaviour-inducing weapons, with its deliberately released neurochemical signal, transmitted via SIM cards, which causes people to become murderously violent, 'culling' the human race to avert its extinction.

More recently, biological weapons have been portrayed in a number of television series, e.g. Jason Rothenberg's *The 100* (2014), Michael Bay's *The Last Ship* (2014), Ronald D. Moore's *Helix* (2014), Michael McGowan's *Between* (2015), Steven Spielberg's *Falling Skies* (2015) and Julie Plec's *Containment* (2016). Video games, too, have proved a popular medium for imagining deliberate diseases scenarios and bring a uniquely immersive and 'lived' first-person experience, e.g. *Command and Conquer: General* (2003), *Acts of War: Direct*

Action (2005), *Dead Island* (2011), *Crysis 2* (2011), *Plague Inc.* (2012), *Call of Duty: Advanced Warfare* (2014), *Batman: Arkham Knight* (2015), and *The Division* (2016).

While by no means complete, this brief review of fictional depictions of biological weapons have highlighted some of the rich material available for analysis. In the concluding section, we outline some of the key research questions we believe important for future work in this field.

Conclusion

This chapter has outlined some of the difficulties and uncertainties in assessing the future threat from biological warfare. In this context, it remains important to think about the more immediate drivers and shapers of the threat, such as new developments in science, the changing nature of conflict and the emergence of new sub-state actors. We have argued, however, that we should also pay attention to less tangible ways in which our perception of the threat is shaped and articulated. In particular, we have little to no understanding of how popular culture provides tools and resources for considering the threat.

Various approaches can be taken to systematically explore the impact of science fiction on political thinking and the way in which it shapes how biological weapons are 'seen'. From our perspective, some of the key research questions for future work in this area are:

- What are the biological threats 'brought into existence' through popular culture? How are these portrayed? How do they relate to the contemporaneous social, political and technical contexts? Is there a dominance of Western fictional imaginaries? What is at stake in these portrayals?
- How are scenarios, characters, technologies, metaphors, images and vocabularies from science fiction brought into technical, political and public discourses? How do fictional accounts provide points of reference for intelligence officers, military officers, biosecurity experts, doctors, epidemiologists, politicians, civil servants, disarmament diplomats, campaigners and pressure groups (e.g. Carpenter 2016; Young and Carpenter 2018), activist scientists and the wider public? How do they shape the threats stakeholders see and prepare for? What are the conceptual exchanges?
- In what ways does popular culture provide a space for moral debate around advancing biological science and possibilities for militarization? How is the ethics of biological weapons development and use represented? How do these representations unite members of a social community in shared perceptions of futures that should or should not be realized? How are these representations drawn on, or opposed, in political contexts?
- To what extent do fictional imaginings follow, mirror or drive technical, political and public debates around future biological threats? How might they create markets of innovation for prospective technologies?

There are further directions to be considered. Most, though not all, academic studies of science fiction dwell on Western cultures; and they tend to shy away from empirical studies of how audiences actually consume and make use of popular culture.

Biological weapons are a pervasive yet difficult threat to address; they may have their roots in scientific developments but they are also significant cultural products. Delving into the rich complexity of the cultural spaces in which these weapons are conceived enables fictional portrayals to be deliberately, rather than unconsciously and uncritically, taken into account. A greater understanding of anticipatory knowledge production may also help generate novel ideas about their control and elimination, as well as enable a greater possibility of shaping the 'looping effects' (Hacking 2001) of envisioned futures.

References

Allied Command Transformation (2016) *Vision of Warfare: 2036*, Norfolk, VA: Allied Command Transformations.

Balmer, B. (2001) *Britain and Biological Warfare: Expert Advice and Science Policy, 1930–65*, Basingstoke: Palgrave.

Balmer, B., McLeish, C. and Spelling, A. (2016) 'Preventing "A Virological Hiroshima": Cold War Press Coverage of Biological Disarmament', *Journal of War and Culture Studies* 9(1): 74–90.

Ben Ouagrham-Gormley, S. and Vogel, K. M. (2016) 'Gene Drives: The Good, the Bad, and the Hype', *The Bulletin of Atomic Scientists*, 14 October. Online. Available: https://thebulletin.org/2016/10/gene-drives-the-good-the-bad-and-the-hype (accessed 14 October 2016).

Bruner, R. and Lentzos, F. (2017) 'Neuroscience – and the New Weapons of the Mind', *The Bulletin of Atomic Scientists*, 27 October. Online. Available: https://thebulletin.org/2017/10/neuroscience-and-the-new-weapons-of-the-mind (accessed 27 October 2017).

Bucht, G., Hart, J., Hjalmarsson, K., Lindblad, A., Roffey, R., Sundqvist, R., Trogen, L., Zanders, J. P. and Westerdahl, K. S. (2003) *Iran's Disarmament and Arms Control Policies for Biological and Chemical Weapons, and Biological Capabilities*, Umeå, SE: Swedish Defence Research Agency.

Carpenter, C. (2016) 'Rethinking the Political/-Science-/Fiction Nexus: Global Policy Making and the Campaign to Stop Killer Robots', *Perspectives on Politics* 14(1): 53–69.

Carus, W. S. (2002) *Bioterrorism and Biocrimes: The Illicit Use of Biological Agents since 1900*, Amsterdam, NL: Fredonia Books.

Carus, W. S. (2017) 'A Century of Biological-Weapons Programs (1915–2015): Reviewing the Evidence', *Nonproliferation Review* 24(1–2): 129–53.

Caves Jr., J. P. and Carus, W. S. (2014) *The Future of Weapons of Mass Destruction: Their Nature and Role in 2030*, Occasional Paper 10, Washington, DC: National Defense University Press.

Commission on the Intelligence Capabilities of the United States Regarding Weapons of Mass Destruction (2005) *Report to the President of the United States*.

Corcos, C (2003) 'Biological Warfare and Law in Film and TV: Some Thoughts on the Links between Real Life and Reel Life', *Picturing Justice: The Online Journal of Law and Popular Culture.* Online. Available: http://usf.usfca.edu/pj/biowarfare_corcos.htm

(accessed 8 July 2014). (The journal ceased publishing in 2006 and an attempt to find the article online on 28 February 2018 failed.)

Costa, H. and Baños, J. (2016) 'Bioterrorism in the Literature of the Nineteenth Century: The Case of Wells and the Stolen Bacillus', *Cogent Arts and Humanities* 3(1): 1224538.

Curtis, R. (1994) 'Narrative Form and Normative Force: Baconian Story-Telling in Popular Science', *Social Studies of Science* 24(3): 419–61.

Davies, S. R. and Horst, M. (2016) *Science Communication: Culture, Identity and Citizenship*, Basingstoke: Palgrave Macmillan.

Edelman, M. (1995) *From Art to Politics: How Artistic Creations Shape Political Conceptions*, Chicago: University of Chicago Press.

Erikson, M. (2016) *Science, Culture and Society*, Cambridge: Polity.

Gil, S. (2018) 'It's Alive in the Laboratory of the Mind: Frankenstein, Thought Experiment and Facing the Future of Science', *Journal of Science and Popular Culture* 1(1): 27–41.

Gould, C. (2005) *South Africa's Chemical and Biological Warfare Program 1981–1995*, Doctorate thesis in fulfilment of a doctorate of History, Rhodes University.

Gregory, J. and Miller, S. (2000) *Science in Public: Communication, Culture, and Credibility*, London: Perseus Publishing.

Guillemin, J. (1999) *Anthrax: The Investigation of a Deadly Outbreak*, California: University of California Press.

Guillemin, J. (2005) *Biological Weapons: From the Invention of State Sponsored Programs to Contemporary Bioterrorism*, New York: Columbia University Press.

Guillemin, J. (2017) *Hidden Atrocities: Japanese Germ Warfare and American Obstruction of Justice at the Tokyo Trial*, New York: Columbia University Press.

Hacking, I. (2001) *The Social Construction of What?*, Cambridge, MA: Harvard University Press.

Hård, M. and Jamison, A. (2005) *Hubris and Hybrids: A Cultural History of Technology and Science*, London: Routledge.

Haynes, R. D. (1994) *From Faust to Strangelove: Representations of the Scientist in Western Literature*, Baltimore: Johns Hopkins University Press.

InterAcademy Partnership (IAP) (2015) *The Biological and Toxin Weapons Convention: Implications of Advances in Science and Technology*, Conference Report.

Jasanoff, S. (2015) 'Future Imperfect: Science, Technology, and the Imaginations of Modernity', in S. Jasanoff and S.-H. Kim (eds) *Dreamscapes of Modernity: Sociotechnical Imaginaries and the Fabrication of Power*, Chicago: University of Chicago Press, 1–33.

Jha, A. (2013) 'Google's Sergey Brin Bankrolled World's First Synthetic Beef Hamburger', *Guardian*, 5 August. Online. Available: www.theguardian.com/science/2013/aug/05/google-sergey-brin-synthetic-beef-hamburger (accessed 5 March 2019).

Kaldor, M. (2007) *New and Old Wars*, Stanford, CA: Stanford University Press.

Kaldor, M. (2013) 'In Defence of New Wars', *Stability: International Journal of Security and Development* 2(1): 1–16.

King, J. and Strauss, H. (1990) 'The Hazards of Defensive Biological Warfare Programs', in S. Wright (eds) *Preventing a Biological Arms Race*, Cambridge, MA: The MIT Press, 120–32.

Kirby, D. (2010) 'The Future Is Now: Diegetic Prototypes and the Role of Popular Films in Generating Real-World Technological Development', *Social Studies of Science* 40(1): 41–70.

Koblentz, G. D. (2017) 'The De Novo Synthesis of Horsepox Virus: Implications for Biosecurity and Recommendations for Preventing the Reemergence of Smallpox', *Journal of Health Security* 15(6): 620–8.

Kohn, M. (1994) 'Stretched Genes', *The Observer*, 6 March 1994: 4.

Kupferschmidt, K. (2017) 'How Canadian Researchers Reconstituted an Extinct Poxvirus for $100,000 Using Mail-Order DNA', *Science*, 6 July. Online. Available: www.sciencemag.org/news/2017/07/how-canadian-researchers-reconstituted-extinct-poxvirus-100000-using-mail-order-dna (accessed 5 March 2019).

Kupferschmidt, K. (2018) 'A Paper Showing How to Make a Smallpox Cousin Just Got Published: Critics Wonder Why', *Science*, 19 January. Online. Available: www.sciencemag.org/news/2018/01/paper-showing-how-make-smallpox-cousin-just-got-published-critics-wonder-why (accessed 5 March 2019).

Lentzos, F. (2016) *Biological Threats in the 21st Century: The Politics, People, Science and Historical Roots*, London: Imperial College Press.

Lentzos, F. (2017) 'Ignore Bill Gates: Where Bioweapons Focus Really Belongs' *The Bulletin of Atomic Scientists*, 3 July. Online. Available: https://thebulletin.org/2017/07/ignore-bill-gates-where-bioweapons-focus-really-belongs (accessed 5 March 2019).

Lentzos, F. (2018) 'How Do We Control Dangerous Biological Research?' *The Bulletin of Atomic Scientists*, 12 April. Online. Available: https://thebulletin.org/2018/04/how-do-we-control-dangerous-biological-research (accessed 5 March 2019).

Lentzos, F. and Invernizzi, C. (2018) 'DNA Origami: Unfolding Risk?' *The Bulletin of Atomic Scientists*, 25 January. Online. Available: https://thebulletin.org/2018/01/dna-origami-unfolding-risk (accessed 5 March 2019).

Martin, S., Clunan, A. L. and Lavoy, P. (2008) *Terrorism, War or Disease? Unravelling the Use of Biological Weapons*, Palo Alto, CA: Stanford University Press.

Miller, C. A. and Bennett, I. (2008) 'Thinking Longer Term About Technology: Is there Value in Science Fiction-Inspired Approaches to Constructing Futures?' *Science and Public Policy* 35(8): 597–606.

Miller, J., Engelberg, S. and Broad, W. (2001) *Germs: The Ultimate Weapon*, London: Simon & Schuster.

Mulkay, M. (1996) 'Frankenstein and the Debate over Embryo Research', *Social Studies of Science* 21(2): 157–76.

Nexon, D. H. and Neumann, I. B. (2006) 'Introduction: Harry Potter and the Study of World Politics', in D. H. Nexon and I. B. Neumann (eds) *Harry Potter and International Relations*, Lanham, MD: Rowman & Littlefield, 1–23.

Nolan, B. R. (2013) 'Information Sharing and Collaboration in the United States Intelligence Community: An Ethnographic Study of the National Counterterrorism Center', Doctorate thesis in fulfilment of a doctorate in Sociology, University of Pennsylvania.

Noyce, R. S., Lederman, S. and Evans, D. H. (2018) 'Construction of an Infectious Horsepox Virus Vaccine from Chemically Synthesized DNA Fragments', *PloS ONE* 13(1): e0188453.

Rappert, B. and Gould, C. (2017) *Dis-Eases of Secrecy: Tracing History, Memory and Justice*, Johannesburg: Jacana Media.

Romeo, N. (2017) 'Better Business through Sci-fi', *The New Yorker*, 30 July. Online. Available: www.newyorker.com/tech/annals-of-technology/better-business-through-sci-fi (accessed 5 March 2019).

Sleigh, C. L. (2011) *Literature and Science*, Basingstoke: Palgrave Macmillan.

Thorpe, C. (2004) 'Violence and the Scientific Vocation', *Theory, Culture and Society* 21(3): 59–84.

Thorpe, C. and Gregory, J. (2010) 'Producing the Post-Fordist Public: The Political Economy of Public Engagement with Science', *Science as Culture* 19(3): 273–301.

Tucker, J. (2000) 'Motivations for and against Proliferation: The Case of the Middle East', in R. A. Zilinskas (ed.) *Biological Warfare: Modern Offense and Defense*, Colorado and London: Lynne Rienner, 27–52.

Turney, J. (2000) *Frankenstein's Footsteps*, New Haven: Yale University Press.

Tyler, A. and Kilmowski, A. (1991), 'The Frankenstein Factor', *Guardian*, 16 March 1991: 8.

United Kingdom of Great Britain (2013) 'We Need to Talk about Compliance: A Response to BWC/MSP/2012/WP.11'. Online. Available: www.unog.ch/80256EDD006B8954/(httpAssets)/B6A0C5EB28982274C1257B9B00553CE9/$file/UK+Compliance+WP.pdf (accessed 5 March 2019).

US State Department (2018) *2018 Report on Adherence to and Compliance with Arms Control, Non-Proliferation, and Disarmament Agreements and Commitments*, Washington, DC: Arms Control, Verification and Compliance Bureau (AVC).

Vogel, K. M. (2008) '"Iraqi Winniebagos™ of Death": Imagined And Realized Futures of US Bioweapons Threat Assessments', *Science and Public Policy* 35(8): 561–73.

Vogel, K. M. (2013) *Phantom Menace or Looming Danger? A New Framework for Assessing Bioweapons Threats*, Baltimore, MA: Johns Hopkins University Press.

Vogel, K. M. (2016) 'Aftershocks of the 2001 Anthrax Attacks', in F. Lentzos (eds) *Biological Threats in the 21st Century: The Politics, People, Science and Historical Roots*, London: Imperial College Press, 211–37.

Wald, P. (2008) *Contagious*, Durham: Duke University Press.

Weldes, J. (2003) 'Popular Culture, Science Fiction and World Politics', in J. Weldes (eds) *To Seek out New Worlds: Science Fiction and World Politics*, London: Palgrave, 1–27.

Wheelis, M. (1999) 'Biological Sabotage in World War I' in E. Geissler and J. E. van Courtland Moon (eds) *Biological and Toxin Weapons: Research, Development and Use from the Middle Ages to 1945*, Oxford: Oxford University Press, 35–62.

Wheelis, M., Rózsa, L. and Dando, M. (2006) *Deadly Cultures: Biological Weapons since 1945*, Cambridge and London: Harvard University Press.

White, H. (1987) *The Content of the Form: Narrative Discourse and Historical Representation*, Baltimore: Johns Hopkins University Press.

Willis, M. (2006) *Mesmerists, Monsters, and Machines*, Kent, OH: The Kent State University Press.

Wright, S. (2007) 'Terrorists and Biological Weapons: Forging the Linkage in the Clinton Administration', *Politics and the Life Sciences* 25(1–2): 57–115.

Young, K. L. and Carpenter, C. (2018) 'Does Science Fiction Affect Political Fact? Yes and No: A Survey Experiment on "Killer Robots"', *International Studies Quarterly* 62(3): 562–76.