3 Past Pathogens and Precarious Futures

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Over the past decades, ancient DNA (aDNA) has emerged as a culturally appealing means of reimagining the connection between the past and the present. In public discussions, aDNA research is often portrayed as providing a material, indisputable link to a prehistoric time. Such a portrayal is based on the idea that aDNA constitutes a fixed, immutable entity that can be unveiled through scientific observation to tell stories about how we became "us."[1] For example, genetic ancestry tests that promise to trace customers' "Neanderthal" or "Denisovan" ancestry,[2] or excited media portrayals of aDNA sequences retrieved from hominin remains,[3] seek to root us in a particular version of the past that may be at odds with knowledge produced within archaeological research, communal tradition, or traditional family genealogy.[4] Importantly, the presumed genetic connection between the past and the present is also understood to be shaping the very contours of the future through, for example, communities and identities that have emerged around geneticized belonging.[5] While the apparent naturalness of aDNA as a means of belonging has been challenged by scholars noting that paleogenomic knowledge relies on choices of datasets, methods, and statistical models, aDNA remains a highly appealing, affectively invested object in cultural discourse.[6]

However, hominin and animal aDNA is not the only type of genetic material that has fueled discussion about how the distant past shapes the present. This chapter turns to another type of ancient genetic material—that of past pathogens—to understand the role of aDNA as a means of imagining trajectories between the past, present, and future. Pathogens are biological entities able to cause disease. They include, for example, bacteria and viruses. Most pathogens contain some type of genetic material, yet there are also crucial differences in their organization and functioning. For example, bacteria can multiply on their own, whereas viruses require a host cell to replicate.

When frozen past pathogens are thawed, some of them can, at least hypothetically, be reactivated and cause disease. Pathogen aDNA thus carries a capacity that human or animal aDNA lacks, as the latter cannot spontaneously come "alive" and become a new living organism. Yet, notably, traces of ancient pathogens are often discovered while analyzing hominin and animal aDNA from old remains.[7] Archaeological and paleontological sites are therefore increasingly seen as a potential source of not only hominin and animal aDNA, but also pathogen aDNA.

Like aDNA from early hominin remains, discovered pathogen aDNA has received considerable public attention. However, whereas the former has mostly garnered fascination, past pathogen discoveries have invoked concerns. Cultural anxieties around past pathogens focus on the perceived liveliness of pathogens as material entities. Such anxieties center on the idea that the genetic material in past pathogens is essentially different from contemporary pathogens and, in the right circumstances, might give rise to reemerging illness. In other words, past pathogens are represented as being potentially able to spontaneously shape our destinies and to hold the future a prisoner of the past. Understanding how past pathogens are conceptualized in culture and science thus complicates the current popular understanding of aDNA as simply telling the story of our genetically rooted belonging. The temporal trajectories between the past, present, and future imagined through aDNA from pathogens are structured by affective tensions and societal concerns that are not typically present in cultural portrayals of hominin aDNA as a genetic document from the past.

Cultural representations of past pathogens center on a particular context: permafrost, ground that is frozen throughout the year for several consecutive years. In cultural discourse and popular science, permafrost is often portrayed as nature's "freezer" because it has emerged as a source of very old biological material that would not have survived in warmer temperatures. Crucially, this freezer is thawing with climate change, thereby exposing old biological material. With cases such as "Ötzi the Iceman," whose 5,000-year-old remains were discovered in melting ice in the Alps in 1991,[8] or the 2010 reconstruction of the first ancient human genome from 4,000-year-old hair found in permafrost in Greenland,[9] permafrost has increasingly been seen as a gateway to previously unknown evolutionary history and early population movement. At the same time, researchers have retrieved traces of deadly pathogens, such as those causing bubonic plague or smallpox, as well as previously unknown viruses and microbes, in the melting permafrost.[10] These examples suggest that past pathogens emerging from permafrost not only are sources of knowledge, but may also in some cases constitute potentially viable entities. This is reflected in how past pathogens buried in permafrost are often portrayed as sharing a likeness with refrigerated viral and bacterial samples stored in a microbiology lab.

The idea of an unknown viral or microbial threat lurking in melting permafrost is present in both scientific and public discourse. For example, the review article "Future Threat from the Past" by medical researchers Amr El-Sayed and Mohamed Kamel posits remains buried in permafrost as objects of particular concern for the future of human life.[11] The authors reflect on the revival of "*Bacillus sphaericus* and *Staphylococcus succinus* . . . from 25 to 40 million-year-old Dominican amber." Other articles highlight the urgency of the issue while noting that little is known about whether old microbial and viral material released from permafrost ground constitutes a direct risk to human health and in what circumstances such risk might materialize.[12] Concerns about the vitality of emerging pathogens are echoed in media stories, such as the 2017 article "There Are Diseases Hidden in Ice, and They Are Waking Up," originally published on the BBC's website. It describes how "permafrost soil is the perfect place for bacteria to remain alive for very long periods of time, perhaps as long as a million years," which means that "melting ice could potentially open a Pandora's box of diseases."[13] In a similar vein, a *Scientific American* article called "Deep Frozen Arctic Microbes Are Waking Up" highlights the unpredictability of dormant pathogens, warning that "organisms that co-evolved within now-extinct ecosystems . . . may also emerge and interact with our modern environment in entirely novel ways."[14]

In this chapter, I locate a key tension at the heart of cultural and technoscientific visions of how past pathogens in permafrost may shape the future. The chapter engages with two cases: an unexpected anthrax outbreak in Siberia in 2016 and the reconstruction of the 1918 pandemic influenza virus. The cases demonstrate two different potentialities. In the first one (anthrax), the past unexpectedly takes over the present; in the second one (pandemic influenza), the past is drawn on to prepare for future pandemics. These differences make visible the ambiguous role of past biological material in the societal search for future health. I will draw from materials ranging from bioscientific articles to media texts and popular science articles on discoveries of past pathogens in permafrost. These materials shed light on how past pathogens and pathogen aDNA discoveries are shaping the ways in which the connection between the past, present and future is imagined in contemporary society.

The Cryopolitics of Pathogens and Permafrost

Old pathogens and aDNA emerging from permafrost are part of the larger politics of freezing and thawing life. Such politics have been called "cryopolitics," a term coined by historian Michael Bravo and physicist Gareth Rees.[15] Science and technology studies scholars Joanna Radin and Emma Kowal have developed the concept further to address technologies and practices of freezing and thawing in biomedicine and science.[16] They approach frozen life as "latent life," a liminal state in which biological matter is neither alive nor dead, yet may—in suitable conditions—come alive.[17] This conceptualization of cold temperature, time, and liminality helps to shed light on how past pathogens and their genetic material, when emerging from the frozen ground, are perceived to carry a potentiality to shape the future. Radin and Kowal highlight that cryopolitics centers on the indeterminacy of that future.[18] In the case of pathogens and permafrost, the link between what has been and what will be is largely unknown, heightening the affective stakes of permafrost discoveries. Old pathogens may, or may not, engender illness or death.

Different practices and technologies of freezing and thawing life have been discussed widely in science and technology studies as well as other social sciences in recent years.[19] The emergence of past pathogens from permafrost resonates with practices of freezing and thawing life-giving entities such as blood, eggs, sperm, embryos, and plant seeds. Like these entities, bacteria and viruses carry the potentiality of generating or shaping life. Yet, there is a crucial difference: the awakening of latent life emerging from permafrost is in itself not a technoscientific, controlled event—although it may result from human action responsible for warming climates. Rather, the melting of permafrost triggers the need for technoscientific intervention, such as public health management and genetic sequencing, including potential manipulation of the retrieved genetic material to create means of managing future diseases.

The cryopolitics of frozen pathogens is embedded in the cryopolitics of permafrost. Permafrost is not just any ice or cold. It is entangled with complex histories and the politics of place and difference. Writing in the context of the North American Arctic, anthropologist Jennifer Hamilton notes that arctic cold has been seen in a popular evolutionary framework as a symbol of a lack of civilization as well as a resource to be exploited by capitalist systems outside the Arctic, for example as a source of frozen meat.[20] In such histories, Hamilton notes, cold is associated with often stereotypical perceptions about Indigenous people living in the Arctic, with the result that cold temperatures have long been seen as a rationale for imperialism and settler colonialism. This colonialist logic is repeated in the long history of portraying the Arctic region and its Indigenous populations—both present and past communities—as a particularly important source of contemporary and ancient DNA through which scientists could presumably access human evolutionary history.[21] Paying attention to this popular association between indigeneity and cold is crucial in order to understand how ideas of pasts and futures are invoked and reinforced in cultural discourses around the two cases analyzed in this chapter. In both cases, the popular association between indigeneity and cold structures, for example, what kind of technoscientific interventions are perceived as necessary to prepare for and prevent future epidemics. Rooted in the colonialist logic, the association of cold and indigeneity also reinforces a sense of "otherness" and danger around Arctic communities and environments, as old pathogens are portrayed in popular discourse as lying in wait.

Finally, permafrost is also materially distinct from other forms of ice and cold. Landscape architecture scholar Leena Cho traces the emergence of permafrost "as an idea" through the development of US permafrost science and engineering.[22] Cho notes that permafrost as a material entity is "active, generative and vibrant," as it is continuously reshaped through changes in temperature.[23] Permafrost's vibrancy also arises from its mixture of organic and inorganic materials: as a place "where various things across earth's time—including ancient microbes, hydrocarbons, roots, toxins, scientific probes and building foundations—have been accumulated, separated and reconstituted," permafrost is unpredictable in its local melting patterns.[24] Permafrost, then, is plural, situated and entangled with other ecologies and infrastructures.

Revisiting the concept of cryopolitics, Michael Bravo highlights this vibrancy, noting how ice that has built up slowly over years can thin remarkably quickly within a few months.[25] Yet, the futures that may emerge from melting permafrost are not without limits. For example, Bravo explains, there may be no point of return: "The thin layer at the top of permafrost can slowly melt and refreeze annually, but when a critical threshold of permafrost melt takes place it collapses and does not regain its structure when refrozen."[26] Crucially, such thresholds shape whether and when forms of potential life—microbes, viruses, and genetic material—may emerge from organic matter such as remains buried in permafrost. This sense of unpredictability adds to the feeling of danger associated with past pathogens in cultural discourse.

The 2016 Anthrax Outbreak in Siberia

In July 2016, a local anthrax outbreak took place in the Yamalo-Nenets autonomous district in Siberia. A twelve-year-old boy died, dozens of people from the nomadic herding community were affected, and over 2,000 reindeer died of illness. The cause of the outbreak has been linked to the summer heatwave, which had reached 35 degrees Celsius, and the subsequent thawing of permafrost, as well as to longer-term patterns of climate change.[27] It was widely suggested at the time that the unusual heat had exposed a reindeer carcass preserved from the previous anthrax outbreak in the region in 1941. It thus appears that anthrax spores had survived seventy-five years in permafrost without losing their capacity to infect organisms.[28]

The 2016 anthrax outbreak raised considerable international interest. Part of this attention likely arose from the affectively charged cultural association between anthrax and bioterrorism—an association cemented in cultural discourse through the anthrax attacks that took place in the United States in 2001, shortly after 9/11. However, considerable attention focused on permafrost and climate change. Commentators asked: If there were large numbers of cattle burial sites in Siberia and other Arctic areas and the climate kept getting warmer, would there be regular anthrax outbreaks in such regions in the future? What other pathogens lay dormant in permafrost that could awaken like anthrax? These themes were repeated across the media. For example, an article on the website of National Public Radio (NPR) in the United States concluded: "The question for researchers is: Could these pathogens—like anthrax—ever be reactivated?"[29] A piece in *Scientific American* on the anthrax outbreak referred to how "the zombie microbes lurking in the permafrost" are "unknowable and unpredictable in their timing and ferocity,"[30] and a news article in the *Barents Observer* was titled "Scientist: Yamal Anthrax Outbreak Could Just Be the Beginning."[31] Likewise, the *Disease Daily* website noted that the case "raises questions about the potential impact of climate change on other pathogens suspended in the ice," as, for example, "smallpox and bubonic plague are also likely embedded in the Siberian ice."[32] Media and other cultural responses, then, extended beyond the case itself to look at the larger issue of melting permafrost. As a result, the anthrax spores released from the ice emerged as symbolic of all old pathogens presumably preserved in the frozen ground.

Much of the coverage of the 2016 anthrax outbreak portrayed the permafrost as a freezer. In the NPR piece mentioned above, for instance, environmental virologist Jean-Michel Claverie described the permafrost soil in the Yamal region as "a giant freezer" that provided "very, very good conditions for bacteria to remain alive for a very long time."[33] This framing connects the reindeer carcass exposed from the melting Siberian permafrost to larger cryopolitics, in which cold temperatures are manipulated to extend life, for example, by freezing embryos for future use.

However, the 2016 anthrax case differs from this technoscientific framework in a crucial way: the freezing and thawing of decades-old animal carcasses is beyond the immediate control of human actors. The media coverage of the 2016 anthrax outbreak clearly demonstrates the affective intensities that accompany this unpredictability. For example, an article in the *Washington Post* based on an account by a University of Missouri scientist describes how anthrax spores "play the long game, waiting in the soil for the temperatures to rise. Once it hits a certain threshold, they morph back into a more mobile, infectious state."[34] In a classic anthropomorphic rhetorical twist, the dormant bacteria emerge as uncanny actors with the power to shake the foundations of human life and society. They are not objects frozen by humans for technoscientific manipulation of life; instead, they are represented as invisible, potentially treacherous strangers within our seemingly familiar world.

At the same time, permafrost itself emerges as active and vibrant. While this is reflected in media stories of how ice that should stay frozen is melting at an alarming pace, it is particularly central to scientific accounts of pathogens, permafrost, and climate change. In an article published in 2011 and referenced in several of the 2016 news stories, medical researchers Boris Revich and Marina Podolnaya warn about the prospect of anthrax emerging at cattle burial sites in the Russian North.[35] In a now ominous tone, the authors predict that resulting from "permafrost melting, the vectors of deadly infections of the 18th and 19th centuries may come back, especially near the cemeteries where the victims of these infections were buried."[36] Crucially, Revich and Podolnaya arrive at this view from an understanding of the melting patterns of permafrost as situated and heterogeneous:

> As the permafrost temperatures in Yakutia increase, permafrost degradation becomes evident. For example, the depth of permafrost varies between 250 and 350 m in the center of this region (Yakutsk city). Under natural conditions, the depth of seasonal melting is 1.5–1.7 m for clay loams, 1.6–2.0 m for sand clays, and 2.0–2.5 m for sands. The temperature of surface layer of permafrost is predicted to increase by 1.5–2°C in West Siberia and Yakutia, and by 1.0–2.0°C in Chukotka and north regions of Far East.[37]

Here, permafrost is constantly shaped through local dynamics involving temperatures and the material qualities of the ground. Likewise, in an article published in 2020, environmental scientist Elisa Stella and colleagues examine permafrost's cyclical nature of wakefulness and how it may affect dormant anthrax spores. Developing a mathematical model that accounts for seasonal fluctuations rather than simply annual changes, they argue that "the seasonal and inter-annual dynamics of the active layer, and of the top surface of permafrost, can critically control the viability of spores and, in turn, the risk of triggering anthrax outbreaks."[38]

In these two examples from scientific literature, futures become pinned to the unpredictable, situated capacities of permafrost in specific material locations. The accounts thereby reflect Bravo's and Cho's theorization of permafrost as never stable and thus never quite manageable. The two examples also shift the focus of attention from the anthrax spores to the material entanglements of ice and soil as capable of shaping futures of health and illness. Affects such as anxiety and concern become attached to this unpredictability of melting ice and its potential ability to mold the future. At the same time, the ability of anthrax spores to come alive and cause outbreaks appear as dependent on these local peculiarities of vibrant permafrost. The perceived animacy of both anthrax spores and melting layers of permafrost are reinforced through their mutual entanglements.

Furthermore, the capacities of the anthrax spores and permafrost are made sense of through ideas of indigeneity in cultural discourses around the 2016 outbreak. As Hamilton notes, indigeneity and permafrost are historically entangled in cultural perceptions and are often interpreted through a popularized evolutionary framework of past-oriented (Indigenous) versus future-oriented (technoscientific) societies.[39] In the anthrax case, the nomadic herders were perceived to have unintentionally played a role in the spread of the outbreak since their herding practices moved a large number of reindeer through small, anthrax-contaminated space.[40] Furthermore, the culture of the herders was sometimes constructed as part of the problem. An article in *Deutsche Welle*, for instance, quotes a governor's spokesperson saying that one of the families who were ill "ate reindeer meat raw and drank the blood," adding that "the nomads do have this custom."[41] For the most part, though, indigeneity remained a relatively unprecise reference point whose affective power lay in the historically cemented popular association between indigeneity and permafrost rather than in any specific material detail.

In the media coverage of the anthrax outbreak, the association between anthrax, cold, and indigeneity operates through ideas of temporality. Anthrax was not only currently in the wrong place (outside the ice) but also originally in the wrong place (in the surface layers of permafrost). The burial practices of the past and unmarked graves were understood to have put anthrax in the wrong place. Anthrax was also in the wrong time: it belonged to the past, not the present nor the future.

At the same time, indigeneity has been commonly associated in popular discourse with the absence of modernity and as presumably unable to reach to the future.[42] Such organization of temporality into (presumably) neatly separable temporal zones—past, present, and future—is the cornerstone of technoscientific ideas of progress. It assumes that the three temporal zones should be kept separate and that the past should not claim a hold over the future. Building on such spatiotemporal politics of cold, indigeneity, and pathogenicity, the nomadic herders became seen as symbolic of the anthrax-ridden past threatening the future. The reindeer carcass as a source of past anthrax spores played a key role in this representation, as the connection between reindeer and indigeneity has a firm place in the imperialist imagination.[43] Familiar colonial images of racialized difference—reindeer herding, burial sites, endless ice—thus emerged in popular representations of the anthrax outbreak as the uncanny that challenges the inevitability of a future. This evocation of indigeneity, permafrost, and the past contributed to the affective intensity around the idea that past pathogens could threaten the future.

Past Pathogens and Evolutionary History

Popular discourses around the 2016 anthrax outbreak focused on the liveliness of the old anthrax spores and their capacity to threaten human health. However, the anthrax outbreak also engendered another type of knowledge: genetic sequencing of anthrax samples. Samples collected from the outbreak provided an entry point to placing the specific pathogen responsible for the outbreak in the context of the evolution of anthrax strains across time and space. This kind of genetic knowledge of pathogens has engendered considerable fascination in culture for its perceived high-tech approach and ability to reach back in time. In this, the sequencing of the anthrax samples from Siberia sits firmly within the larger project of aDNA research, which seeks to understand evolutionary processes through old DNA samples. The sequencing of the 2016 anthrax samples warrants attention, as it shows how aDNA research has expanded across bioscientific research, seeking to turn epidemics into sources of evolutionary knowledge. This case also provides a crucial contrast to the sequencing of the 1918 influenza virus, which—as we will see in the following sections—focused on the prevention of future epidemics. This shows that genetic knowledge of past pathogens occupies an ambivalent position as a means of knowing the past as well as managing the future.

The sequencing of anthrax samples from the 2016 outbreak took place in the context of ancient pathogen genomics. In the past decade in particular, geneticists have sought to identify and sequence pathogens discovered in archaeological and paleontological sites and in environmental samples, producing ancient sequences of pathogens behind, for example, salmonella, cholera, and louse-borne relapsing fever.[44] Central to ancient pathogen genomics is the geneticization and digitization of material differences between pathogens retrieved at different sites and representing different points in time. The resulting reconstructed evolutionary histories of pathogen strains are then employed to investigate how diseases have spread across regions over centuries.

A paper published in the science journal *PLoS ONE* in 2019 demonstrates how aDNA operated as a mode of knowledge production in the case of old anthrax strains.[45] In the paper, microbiologist Vitalii Timofeev and colleagues compared anthrax samples from the Yamal Peninsula linked to the 2016 outbreak and three samples retrieved from permafrost in Yakutia, about 2,000 kilometers east of the Yamal region. In the Yakutia case, a mining-related excavation had led to an unexpected discovery of frozen cave lion remains, and soil samples collected from the discovery site were in a 2016 analysis shown to contain anthrax. However, the anthrax was not connected to the animal remains but was of younger, unknown origin. Three different anthrax strains were identified at the depth of 2, 3, and 4 meters in Yakutia. The genetic sequencing placed the oldest of the Yakutia samples (at the depth of 4 meters) in the same anthrax lineage—the B clade—as the Yamal samples, while indicating that the other two Yakutia samples (discovered closer to the surface) represented two different branches of another lineage—the A clade. Drawing on genetic differences between the samples, the authors suggest that "the third and most recent introduction [of anthrax in Yakutia], detected at minus two meters, occurred as a side effect of Russian conquests and development of agriculture after the 17th–18th century," while "the second introduction detected at minus 2 and minus 3 meters, would be the byproduct of Yakut's population migration from Lake Baikal area after the 14th–15th century."[46] Regarding the oldest of the Yakutia strains, discovered at the depth of 4 meters, the authors propose that "the location in the permafrost and its genetic proximity with the strain independently found in the Yamal peninsula may indicate that it is not more than a few centuries older than the second introduction."[47] Such a comparison of sequenced anthrax samples paints a picture of anthrax as multiple and mutable rather than single and fixed.

This kind of genetically derived knowledge is oriented toward the past in the sense that the sequenced strains were used to understand the coevolution of humans and pathogens. In this, it stands in contrast to the idea of past pathogens as lively entities threatening the future that characterized media responses to the 2016 outbreak. Yet, the boundary between a spontaneous outbreak caused by a past pathogen and the analysis of soil samples from an excavation site for genetic information is not clear-cut. The article by Timofeev and colleagues notes that the anthrax strains from the Yakutia excavation turned out to be virulent when tested on mice.[48] At the same time, the sequencing of the old anthrax strains makes visible that the material and digital are fundamentally entangled. The digitization of anthrax's evolutionary trajectories is enabled through the material differences between strains and samples. Approaching past pathogens within a genetic framework relies, in other words, on vibrant materiality that engendered the differences in the first place. At the same time, the sequencing provides evidence of the material mutability of anthrax as a pathogen, which, instead of being an end point to a history, presumably constitutes a midpoint from where further microbial mutations may arise.

Finally, the comparison of sequences from the outbreak and an excavation site makes visible that the question of cryopreserved and potentially vibrant past pathogens not only is a matter of unexpected processes of thawing but also underlies archaeological and paleontological projects in regions characterized by permafrost. Archaeological or paleontological study of the past in melting ground, the case suggests, could potentially turn into an event that shapes health in the present and the future. Yet, as the rest of this chapter will show, the sequencing of the old anthrax strains differs from the sequencing of the 1918 pandemic virus. In the latter case, the sequence becomes part of a technoscientific project of recreating the past pathogen as a lively, material entity with the hope of proactively preventing death and disease in the future.

Reconstructing the 1918 Pandemic Influenza Virus

The reconstruction of the 1918 pandemic influenza virus illustrates what happens when the past pathogen is not alive but embodies a theoretical potentiality—that is, it cannot spontaneously cause disease but can still be manipulated to produce a live pathogen. Unlike the remarkably durable anthrax spores preserved in permafrost, influenza viruses require a host organism. The case also sheds light on the complex technoscientific apparatuses that are needed to translate a genetic sequence to vibrant biological matter.

The story of the discovery and reconstruction of the "Spanish Flu" pandemic influenza virus that killed some fifty million people in several waves in 1918–1919 is often portrayed as epitomizing how science may use knowledge about past epidemics to prevent future disease.[49] In 1951, Johan Hultin, then a PhD student at the University of Iowa, had an idea for his doctoral work: to search for a sample of the 1918 virus in a permafrost grave. He chose Brevig Mission, an Inuit community in Alaska, where seventy-two of the village's eighty adult inhabitants had died within only five days in November 1918. After gaining permission from the village community, excavation started, but the gathered samples did not contain retrievable and analyzable viral material. Over forty years later, in 1997, virologist Jeffery Taubenberger's team at the Armed Forces Institute of Pathology in Washington, DC, published an analysis of the 1918 virus collected from old lung samples from a US army hospital. As the genetic analysis still had significant gaps, Hultin again traveled to Brevig Mission for another attempt. He and the local team managed to retrieve viral material from the lungs of the frozen body of an Inuit woman. Permafrost had preserved the virus sufficiently to enable genetic sequencing by Jeffery Taubenberger, Ann Reid and their colleagues.[50]

Permafrost as nature's "freezer" operated quite differently in the 1918 pandemic case than in the 2016 anthrax incident. The viral genetic material did not threaten health directly (although researchers, of course, protected themselves to minimize that possibility). Instead, the "resurrection of the 1918 pandemic virus," as it was framed in journalistic discourse, required extensive technoscientific work.[51] First, Taubenberger and colleagues used RNA—ribonucleic acid, the genetic material present in viruses—from stored samples along with the naturally cryopreserved lung samples that Hultin had brought back from Alaska. This combination of different biological materials made it possible to sequence the full viral genome.[52] Second, microbiologist Peter Palese's lab in the Mount Sinai School in New York produced plasmids that contained the genetic components of the virus necessary for the reconstruction of the virus as a material, virulent entity. The plasmids were inserted into human kidney cells to generate the production of the virus by microbiologist Terrence Tumpey at the Centers for Disease Control and Prevention headquarters in Atlanta.[53]

The connection between genetic sequence, the materiality of the virus, and the ability of the virus to cause disease is, however, complicated. In a discussion of the reconstructed 1918 pandemic influenza virus, anthropologist Frédérick Keck notes that genetic knowledge does not translate directly to "life" in the sequencing of naturally cryopreserved past viruses.[54] That is, although DNA is commonly portrayed as the code of life, it cannot generate biological processes—new life, an infection—alone. Furthermore, while the recreated pandemic influenza virus turned out to be highly infectious in animal and tissue tests, it could not be assumed that infectiousness would translate directly to deadliness among humans. Tests designed to identify possible mechanisms behind the mortality of the 1918 pandemic suggested that multiple material features of the recreated virus shaped its virulence.[55] In an ethnographic study of pandemic preparedness, anthropologist Carlo Caduff documents Peter Palese's skepticism about the direct line drawn by politicians and the public between reconstructed sequences and lively pathogens.[56] Caduff observes that *information* about a sequence of a past pathogen has become seen as dangerous—a question of biothreat, even bioterrorism—although highly skilled craft work is needed to reassemble viruses as material, lively entities, and liveliness does not necessarily mean lethality. In fact, pandemic threat often emerges through mutations on a previously harmless virus. Caduff also notes that there is no such thing as *the* 1918 pandemic virus, as viruses are always present in multiple forms.[57] This question of representativeness of the sample is also at the heart of public debates about aDNA research more generally, as samples and datasets from past decades and centuries are always limited in scope.

The reconstruction of the 1918 pandemic virus as a material entity relied on reverse genetics. In reverse genetics, a genetic sequence is used to produce a lively entity through a range of advanced techniques. The sequence may be manipulated to test the effects of mutations on cells or organisms. In the case of the 1918 pandemic virus, reverse genetics generated an entity that had, at least in theory, the potential to threaten human life, had the engineered virus escaped the high-security lab. At the same time, this entity had the capacity, through its recreated vibrancy and ability to cause disease, to show *materially* how the pandemic virus operated, for example, in live lung tissue, a main concern in deadly cases of the 1918 pandemic influenza.

Crucially, the use of reverse genetics to recreate the influenza virus was commonly justified through a link to the prevention of future pandemics: gaining knowledge that would presumably help in responding to new viral strains in the future. For instance, Jeffery Taubenberger and colleagues noted in 2007 that “revealing the biology of a pandemic that occurred nearly 90 years ago is not just a historical exercise,” but something that “may well help us prepare for, and even prevent, the emergence of new pandemics in the 21st century and beyond.”[58] A popular article published in the *American History* magazine and included on the *HistoryNet* website echoes this culturally appealing rationale: “Deciphering how a particular virus operates opens up insights into other viral strains and reveals how they grow, mutate, jump from animal to animal, and attack their hosts. . . . Ideally, someday scientists will build on Hultin and Taubenberger’s work to uncover a genetic Achilles heel in one strain that makes it possible to wipe out all of them.”[59] These quotations point to the affectively charged nature of reconstructed pathogens as cultural objects poised between the past and the future. Their technologically recreated vibrant materiality is portrayed as a threat to futurity as well as a key to securing future health.

Indigenous Samples at the Crossroads of Pasts and Futures

As in the anthrax case, cultural discourses around the reconstruction of the pandemic virus drew on associations between permafrost, cold, and indigeneity. Many scientific and popular accounts carefully mention that Hultin received permission from the Inuit community in Brevig Mission for the excavations and the removal of biological samples.[60] Yet, the use of Inuit human remains places the case within the larger cultural politics and technoscientific histories in which Indigenous biological samples—blood, tissue, genetic sequences—become the sources of knowledge for what is viewed by many research institutions and policy makers as the "common good," the future health of humanity, a framing reflected, for example, in a media portrayal of the reconstruction of the 1918 virus as "a vital service to global public health."[61] What the benefits of the use of Indigenous samples might be for the local community is often unclear, as many scholars have shown.[62]

In their retrospective account of the excavations, Taubenberger, Hultin, and David Morens provide a striking description of the specific materialities that the case relied on. According to them, the fact that the Inuit woman buried in permafrost was obese provided the preconditions for the survival of viral material, as this likely "had preserved the internal organs from decomposition during occasional short periods of thawing within the permafrost. Her lungs displayed the gross appearance of those seen in acute viral pneumonitis, expanded and dark red in colour."[63] Several news stories highlighted Hultin's reconstructed moment of realization that the body in question was not only preserved by the cold but had also become a freezer for the virus.[64] The remains thus emerged as carrying unique physical characteristics as well as being embedded in communal practices such as preservation of land from construction projects. The annual melting patterns of permafrost, the interactions between a unique body and temperature, and the burial practices of the Inuit community enabled the retrieval and sequencing of the virus. This shows that the potential liveliness of past pathogens preserved in permafrost is neither an outcome of some general pattern of thawing nor the result of technoscientific study of generic biological matter.

At the same time, Brevig Mission, and the Inuit woman's unexpectedly preserved body, were embedded in broader cultural ideas of indigeneity, time, and temperature. Whereas the nomadic herders in Yamal were portrayed by some as threatening the proper separation of the past and the future through their herding practices, the perceived embeddedness of the Brevig Mission Inuit community in the past as well as in the cold emerged in popular discourse as a source of both potential future health and as a risk to the future. Such a cultural framing adds intensity to hopes, concerns, and wonder around the potentialities of past pathogens.

While indigeneity is part of the complex relations that led to the retrieval of viral samples in Brevig Mission, these material conditions largely disappear from view when the retrieved lung samples are taken to the genetics lab, sequenced, compared with genetic material from other sources, and used as part of a reconstructed virus. In this chain of technoscientific events, the distance between indigeneity and the virus that once killed so many in Brevig Mission grows step by step. When the origins of the sequence are mentioned, it is often present only in the technical name of the strain from the Brevig sample: the influenza A/Brevig Mission/1/18 (H1N1) virus.[65] Yet, despite this relative invisibility, indigeneity and the temporalities and cold temperature associated with indigeneity in cultural discourse manifest around the case as a sense that the recovered and reconstructed viral material embodies temporal, spatial, and cultural difference. The virus, like the Indigenous human remains in the grave, is portrayed as being "frozen in time."[66] As in the anthrax case, what that difference is remains vague, but it carries associations with the perceived insularity of communal practices and the popular assumption that indigeneity is past-oriented.

Conclusion

This chapter has traced the role of past pathogens and permafrost in contemporary society through two pathogens known to have caused life-threating illness in the past: anthrax and the 1918 pandemic influenza virus. There are crucial differences between them as material entities: while anthrax is a microbe preserved in spores, the pandemic influenza virus is known for its fast mutation rate and dependence on a host organism. These differences demonstrate how different types of pathogens, when emerging or retrieved from permafrost, may open up different trajectories between the past and the future. The perceived durability of anthrax spores through centuries posits it as an uncanny stranger that lies in wait in the frozen ground on which society, facing climate change, relies. The reconstructed pandemic influenza virus, in turn, raises cultural concerns about futures through images of biothreat as well as hopes of preventing future outbreaks through technoscientific manipulation. This ambivalence ties past pathogens affectively with both hopes and concerns about the future of society and the continuity of life as we know it. How past pathogens are framed as potentially viable and unpredictable entities and as sources of genetic information and engineering shapes what kinds of expectations become attached to the search for aDNA in melting ice. At the same time, the ways in which the two cases draw on slightly different constellations of permafrost, indigeneity, and space emphasizes that the potentially lively materiality of past pathogens is always historically and politically situated. These constellations also contribute to affective intensities in how past pathogens are perceived as unknown or knowable.

I opened the chapter by asking how old pathogens emerging or retrieved from permafrost complicate the popular understanding of aDNA as a straightforward link between the past and the present. The chapter has highlighted that at stake in aDNA discoveries is not just our relationship to the past but also the very parameters—narratives, discourses, concepts—through which futures can be imagined. Past pathogens such as anthrax and the 1918 influenza virus unsettle the culturally cherished separation of the past, present, and future, and make visible that this separation is an illusion. The cases also demonstrate that the connections between the past and the future invoked through aDNA are ultimately ambivalent, as the potential liveliness of old pathogens, cryopreserved in permafrost, can materialize as both a threat to and a promise of futurity. In the case of the pandemic influenza virus, these potentialities coexist, intensifying the affective stakes of aDNA as a cultural object. In both cases, affective intensities focus on the unpredictability of the future that may arise from the potential vitality of pathogens, whether that of a spontaneously thawing pathogen (anthrax) or a technoscientifically created entity (pandemic influenza). Critical explorations of this foundational ambivalence as to how the past and future are entangled will help broaden and complicate the ongoing discussion about the cultural role of aDNA.

Notes

1. Prominent examples of this framing of aDNA as a gateway to the past include geneticist David Reich's book *Who We Are and How We Got Here* (Oxford: Oxford University Press, 2018), and geneticist Adam Rutherford's book *A Brief History of Everyone Who Ever Lived: The Human Story Retold through Our Genes* (New York: The Experiment, 2017).

2. Some genetic ancestry testing companies advertise an option for tracing the customer's relationship to early hominins such as Neanderthals and Denisovans (e.g., 23andMe and ADNTRO). For an analysis of how ideas of historical populations are invoked and incorporated into contemporary identity discourse, see, for example, Marc Scully, Steven D. Brown, and Turi King, "Becoming a Viking: DNA Testing, Genetic Ancestry and Placeholder Identity," *Ethnic and Racial Studies* 39, no. 2 (2016): 162–180.

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47. Timofeev et al., "Insights from *Bacillus anthracis*," 16.

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