MAT Medicine Anthropology Theory

FOUND IN TRANSLATION

Still fresh!

Introductory remarks on the English translation of 'Frischeregime'

Alexander Friedrich and Stefan Höhne

Keywords

biopolitics, cryopreservation, history, biotechnology, infrastructure

One of the joys of a collaborative intellectual endeavor is that a small and spontaneous idea can quickly turn into a fascination or even obsession that develops a life of its own. Fueled by mutual enthusiasm, it can become a large-scale scholarly undertaking that eventually absorbs more time and energy than one (or two) can reasonably afford. However, it can also herald great insights and be sheer fun. This article on regimes of freshness is in many ways the intermediate result of such a dynamic. It is the outcome of a long-lasting collective adventure into what we eventually termed the 'cryogenic culture': a large-scale historical formation brought about by the social implementation of artificial coldness since the late nineteenth century. We argue that this culture systematically produces and fundamentally depends on artificial coldness, for example, for food supply, electricity generation, mobility, telecommunication, health care, biomedical products, and reproductive technologies. Today, nearly every aspect of life is affected by refrigeration techniques: we cool food, drugs, semen, cells, blood, organs, tissues, and bodies as well as air condition environments. Increasingly, we also cool and climate control entire cities – even the global climate is an object of concerted (or refused) cooling efforts.

Medicine Anthropology Theory 3, no. 3: 112–154; https://doi.org/10.17157/mat.3.3.457

As an exploratory attempt to make these constitutive functions of refrigeration for modern societies visible, this piece exceeds both the usual length and scope of academic journal articles. It aims at nothing less than to trace the emergence of the cryogenic culture from Lord Francis Bacon's experiments of conserving chickens through stuffing them with snow to the development of cooling chains in the rapidly industrializing slaughterhouses of Chicago in the late nineteenth century, to the rise of cryobiology in the second half of the twentieth century, to the recent formation of the cryobank industry.

In a quite early state of our research, after collaboratively spending several days mapping out the far-reaching impact of cooling technologies on modern society, we half-jokingly started to refer to these interdependent sociotechnical and biopolitical dynamics leading to the cryogenic culture as 'regimes of freshness'. Intrigued by the scope and depth on how cryogenic practices became materialized in our everyday life, we had started to notice the nearly ubiquitous rhetorics and technologies of freshness around us, from calls for research applications ('looking for fresh ideas') to advertisements in the supermarket ('Experience Freshness!').

Originally taking these discourses of freshness as rather circumstantial surface phenomena, we soon discovered that they actually hint at a crucial dynamic in the emergence of cryogenic culture. As refrigeration technologies have enabled a potentially endless delay of natural decomposition of organic substances, this brought about a new understanding of what we regard as 'fresh', or even 'alive', therewith also altering our relation to the biological and the 'bios' as such. Biocentric cooling technologies changed modes of producing, distributing, consuming, and disposing, and thus the way of life in modern societies – thereby modifying traditional relations between time and space, culture and nature, life and death. As we further explored the cultural and theoretical implications of biocentric cooling, we discovered that technologies of freshness eventually gave birth to new forms or states of life: suspended animation, archived documents, genetic information, future life forms, vital feedstock, and speculative biocapital. Since these new forms, states, and modes of life are based on the use of cooling machines and infrastructures, we call them 'cryogenic life' – rendering life as a resource that should be kept vital and fresh for as long as possible. Nowadays, preserved freshness – in terms of perishables, health, youthfulness, or fertility – is a highly contested commodity. Therefore, we eventually stuck to our quirky title, despite the remark of our excellent translator Emily Bereskin that 'in English, "Regimes of Freshness" does sound a little bit like a late-1990s hip-hop act'.

Addressing the technological developments, discursive formations, and social practices leading to cryogenic culture, the phrase 'regimes of freshness' also implies the establishment of a new mode of power in a Foucauldian sense. This insight eventually initiated the original publication of our article in the issue entitled 'Feeding the Planet, Energy for Life' of the interdisciplinary journal *Glocalism* (2014). The journal editors called for papers that could contribute insights to 'a new form of global bio-politics' that no longer can be regarded in the terms of Foucauldian biopower, especially when it comes to food production. According to Foucault (2003, 241), who introduced this concept to describe historically new measures and tools of population control, biopower acts on the maxim: 'Make live and to let die'. Modern ecology and biotechnology, however, are more interested in sustainability and preservation than in letting what is alive die. At first, we actually tried to understand 'regimes of freshness' as an extensive manifestation of biopower on an unprecedented scale. But drawing things together, we came to the conclusion that the large-scale disposition of cooled and frozen life is not just the continuation of biopolitics, now by icy means. Fundamentally concerned with the question of how to preserve fresh food and living matter by refrigeration and how to extend life through cryopreservation, this new, cryogenic form of biopower obviously changed its maxim to: 'Make live and let *not* die'. Thus, we decided to submit our article to the journal, which accepted articles for the special issue 'in any language and of a length chosen by the author', fortunate, because the deadline was already near and time too short for providing a proper translation. So we submitted our lengthy piece on *Frischeregime* in German. To our pleasant surprise, it received quite enthusiastic peer reviews and was eventually published in summer 2014.

Our essay has gained some recognition among our colleagues and peers in Germany, mostly in philosophy of science and technology (see for example in Gramelsberger 2015 and Hubig 2015). However, this research subject is still a quite new and emerging topic, especially for the German-speaking scientific community. Encountering skeptically raised eyebrows is not unusual when we tell colleagues for the first time what we are dealing with: '*Frischeregime?*' A more detailed explanation usually convinces them that this is actually a serious and far-reaching topic worthy of further inquiry. That this phenomenon is still underexplored despite having a crucial impact on many aspects of modern society might lie in the fact that it is traversing (too) many disciplinary borders of the German academic landscape: from history, sociology, economy, and science and technology studies, to biology, anthropology, philosophy, and cultural studies.

The two of us have different disciplinary backgrounds, namely philosophy and history, but we both have strong ties to sociology and cultural studies. When originally discussing our individual research interests, which lie in the philosophical implications of the growing technological transformation of life and the historical impact of logistics and technologies of circulation respectively, we soon discovered our mutual fascination with cooling chains. In starting to map out the philosophical as well as sociocultural implications of these technologies, it became apparent that both our disciplines provide rather limited analytical means to make sense of these phenomena. Either they lack a conceptual framework to develop a theoretical apparatus that would allow for a deeper understanding of the historical emergence of cooling technologies or they neglect the sociocultural dynamics that deemed their implementation so irresistible. Therefore, this research profited intensively from an interdisciplinary approach, actually convincing us that only the entanglement of several academic perspectives will allow us to fully understand the true scope and scale of cryogenic technologies.

Thankfully, in the meantime, a small but growing interdisciplinary network of researchers has formed who work on crucial aspects of biopolitics in the age of cryogenic culture. It often happens in the history of science that different people start to work on similar problems and come to the same conclusions independently. Something of this kind happened here as well. One year after the publication of our article, two other researchers from different disciplines, the anthropologist Emma Kowal (Deakin University) and the historian of science and medicine Joanna Radin (Yale University), published an article on cryo-based indigenous biospecimen collections – coming exactly to the same conclusion concerning the new mode of biopolitics at work here: 'Make live and let *not* die' (Kowal and Radin 2015). The earlier work of Radin, specifically her 2012 PhD thesis entitled 'Life on Ice', has already been of great importance for our study and we are looking forward to the revised version to be published by University of Chicago Press in 2017.

This concurrence of several researchers half a world apart simultaneously beginning to research the rise of the cryogenic culture is far from being a coincidence. With the dissemination of technologies of cryopreservation in recent years, frozen biological substances of any provenance have become valuable and highly contested resources. This not only holds true in reproductive medicine and biotechnology, but also in pharmaceutics, transplantation surgery, the food industry, conservation biology, epidemiology, and public health (Scheper-Hughes 2000; Chrulew 2001; Landecker 2010; Radin 2014; Swanson 2014). Kept as a vital matter in banks, archives, and 'frosty arks', biological collections are opening up new possibilities regarding cryopreserved human specimens, agricultural products, and zoological or pharmaceutical bioprospecting (Parry 2006; Waldby and Mitchel 2006; Kowal, Radin, and Reardon 2013; Kowal and Radin 2015; Waldby 2014; Alpsancar 2017). As these dynamics are gaining momentum, they not only raise economic and political concerns but also continue to spark heated ethic debates among the public and in academia, for example on the jurisdictional frameworks of biobanking; the regulation of specimen collections and biopiracy; the ethics of reproductive technologies, embryo donations, and stem cell research, as well as the eugenic or colonial heritage of frozen archives and cryobanks; and the global climate footprint of cooling and freezing technologies.

While this article tackles all these dynamics, it is still far away from exploring them with the rigor they deserve. Therefore, many questions still remain, for example on the development of medical 'hypothermia', the propagation of refrigerated vaccines, the organ trade, genome editing, 'social freezing', and the global energy consumption of refrigeration, air conditioning, and cryopreservation. Since the original publication of this text in early 2014, several new studies have productively addressed some of these phenomena, such as the above-mentioned study on colonial legacies of the frosty life (Kowal and Radin 2015), the breathtaking expansion of biocapitalist economies (Cooper and Waldby 2014; Parry 2015; Waldby 2015), and the forthcoming edited volume entitled *Cryopolitics: Frozen Life in a Melting World* (Kowal and Radin 2017). While studies in the humanities and social sciences on technologies of cooling and freezing have been barely related to each other so far, the latter book is one of the first attempts at bringing experts from different disciplinary fields together for debating the political and cultural consequences of extending life and deferring death by technoscientific means. Inspired by all these studies, and in productive exchange with international researchers in this field – who are still not all that many in number – we have continued our journey into the cryogenic culture, exploring themes such as new temporal regimes of cryopower (Friedrich 2016) and the rise of the increasingly globalized and highly infrastructured coldscapes or 'cryospheres' (Höhne 2015).

Of course, as Annemarie Mol (2015, 60) has pointed out in *MAT*: 'Simply existing in English is not enough for a text to travel'. However, with the rising interest in the impact of cryogenic technologies on modern culture, we hope that this now translated text will reach a variety of new readers who might be equality fascinated by these phenomena. Maybe, it might even spark further inquiries into the many, mostly unexplored dimensions of cryogenic culture. After all, we are convinced that we are only in the beginning of understanding the impact of artificial coldness on our life, and for many years to come it will offer a perspective on modern society that will remain – well – fresh.

About the authors

Stefan Höhne is a historian and cultural studies scholar at the Center for Metropolitan Studies at Technische Universität Berlin. His dissertation traces the historical subjectivities of the passenger in New York City during the twentieth century. He researches and publishes on urban history and theory and is the editor of the journal *sub\urban*: *Zeitschrift für Kritische Stadtforschung*. Currently, he is working on a global history of sabotage during the Cold War. His recent publications include: 'The Infrastructures of Diversity: Materiality and Culture in Urban Space' edited by Marian Burchardt, Stefan Höhne, and AbdouMaliq Simone, published in *New Diversities* 17 (2015). His email is Stefan.hoehne@metropolitanstudies.de.

Alexander Friedrich holds a PhD in philosophy from Justus Liebig University Giessen (Germany). In his thesis, he examined the theory and history of the 'network' as a key cultural metaphor. As a postdoctoral researcher at the Technische Universität Darmstadt, he investigates the biopolitical aspects of freezing and cooling technologies. He is also exploring new ways for a digital history of concepts, and is coeditor of the *Jahrbuch Technikphilosophie*. His recent publications include: 'The Rise of Cryopower', in *Cryopolitics: Frozen Life in a Melting World*, Emma Kowal and Joanna Radin, eds. (MIT Press, March 2017). He can be contacted at friedrich@phil.tu-darmstadt.de.

References

Alpsancar, Suzana. 2017. 'Von der Cultura zur Option: Wie Samenbanken als Sicherungstechniken Realwerte in Optionswerte verwandeln'. In *Jahrbuch Technikphilosophie,* edited by Alexander Friedrich, Petra Gehring, Christoph Hubig, Andreas Kaminski, and Alfred Nordmann, 427–44. Baden-Baden: Nomos. https://doi.org/10.5771/9783845277677-425.

Chrulew, Matthew. 2001. 'Managing Love and Death at the Zoo: The Biopolitics of Endangered Species Preservation'. *Australian Humanities Review* 50: 137–57.

Chrulew, Matthew. 2011. 'Reversing Extinction: Restoration and Resurrection in the Pleistocene Rewilding Projects'. *HUMaNIMALIA* 2: 4–27.

Cooper, Melinda, and Cathy Waldby. 2014. *Clinical Labor: Tissue Donors and Research Subjects in the Global Bioeconomy.* Experimental Futures. Durham, NC: Duke University Press. https://doi.org/10.1215/9780822377009.

Foucault, Michel. 2003. *Society Must Be Defended: Lectures at the College De France, 1975–1976*. New York: Picador.

Friedrich, Alexander. 2016. 'Die Vergänglichkeit überlisten – Leben und Tod in kryogenen Zeitregimen'. *Jahrbuch Technikphilosophie,* edited by Gerhard Gamm, Petra Gehring, Christoph Hubig, Andreas Kaminski, and Alfred Nordmann, 35–56. Zürich, Berlin: diaphanes.

Gramelsberger, Gabriele. 2015. *Operative Epistemologie: Begriffstheoretische Studie zur Erkenntnis- und Formkraft der Mathematik*. Habilitationsschrift. Technische Universität Darmstadt.

Höhne, Stefan. 2015. 'Kryosphären des Kapitals. Zur urbanen Topologie gekühlten Lebens'. Lecture at Department of Sociology, Technische Universität Darmstadt, 12 January.

Hubig, Christoph. 2015. *Die Kunst des Möglichen III: Grundlinien einer dialektischen Philosophie der Technik*. Bielefeld: transcript. https://doi.org/10.14361/transcript.9783839428122.

Kowal, Emma, and Joanna Radin. 2015. 'Indigenous Biospecimen Collections and the Cryopolitics of Frozen Life'. *Journal of Sociology* 51, no. 1: 63–80. https://doi.org/10.1177/1440783314562316.

Kowal, Emma, and Joanna Radin, eds. Forthcoming. *Cryopolitics: Frozen Life in a Melting World*. Cambridge: MIT Press.

Kowal, Emma, Joanna Radin, and Jenny Reardon. 2013. 'Indigenous Body Parts, Mutating Temporalities, and the Half-Lives of Postcolonial Technoscience'. *Social Studies of Science* 43, no. 4: 465–83. https://doi.org/10.1177/0306312713490843.

Landecker, Hannah. 2010. 'Living Differently in Time: Plasticity, Temporality and Cellular Biotechnologies'. In *Technologized Images, Technologized Bodies,* edited by J. Edwards, P. Harvey, and P. Wade, 211–36. New York: Berghahn Books.

Mol, Annemarie. 2015. 'Who Knows What a Woman Is... On the Differences and the Relations between the Sciences'. *Medicine Anthropology Theory* 2, no. 1: 57–75.

Parry, Bronwyn. 2006. 'New Spaces of Biological Commodification: The Dynamics of Trade in Genetic Resources and "Bioinformation"'. *Interdisciplinary Science Reviews* 31, no. 1: 19–31. https://doi.org/10.1179/030801806x84228.

Parry, Bronwyn. 2015. 'A Bull Market? Devices of Qualification and Singularisation in the International Marketing of US Sperm'. In *Bodies Across Borders: The Global Circulation of Body Parts, Medical Tourists and Professionals,* edited by Bronwyn Parry, Beth Greenhough, Tim Brown and Isabel Dyck, 53–72. London, New York: Routledge.

Radin, Joanna. 2012. 'Life on Ice: Frozen Blood and Biological Variation in a Genomic Age, 1950–2010'. PhD diss., University of Pennsylvania.

Radin, Joanna. 2014. 'Unfolding Epidemiological Stories: How the WHO Made Frozen Blood into a Flexible Resource for the Future'. *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences* 47, part A: 62–73. https://doi.org/10.1016/j.shpsc.2014.05.007.

Radin, Joanna. Forthcoming. *Life on Ice: A History of New Uses for Cold Blood.* Chicago: University of Chicago Press. https://doi.org/10.7208/chicago/9780226448244.001.0001.

Scheper-Hughes, Nancy. 2004. 'The Global Traffic in Human Organs'. *Current Anthropology* 41, no. 2: 191–224. https://doi.org/10.1086/300123.

Swanson, Kara W. 2014. *Banking on the Body: The Market in Blood, Milk, and Sperm in Modern America.* Cambridge, MA: Harvard University Press. https://doi.org/10.4159/harvard.9780674369481.

Waldby, Catherine. 2014. 'Banking Time: Egg Freezing and the Negotiation of Future Fertility'. *Culture, Health & Sexuality* 17, no. 4: 470–82. https://doi.org/10.1080/13691058.2014.951881.

Waldby, Catherine. 2015. 'The Oocyte Market and Social Egg Freezing: From Scarcity to Singularity'. *Journal of Cultural Economy* 8, no. 3: 275–91. https://doi.org/10.1080/17530350.2015.1039457.

Regimes of freshness

Biopolitics in the age of cryogenic culture

This article was originally published in German in 2014 under the title 'FrischeRegime: Biopolitik im Zeitalter der Kryogenen Kultur', in *Glocalism* 1, no. 2. https://doi.org/10.12893/gjcpi.2014.1-2.3.

Abstract

Today, it seems that nearly every aspect of life is affected by cryogenic techniques: we cool our food, environments, drugs, organs, eggs, milk, semen, tissue, blood and much more. Our central argument is that these developments lead to the formation of a new form of life, which in many ways is the antipode of what Agamben calls bare life. In analyzing the emergence of cryogenic culture from a biopower point of view, this study offers a new perspective on how populations are fostered and governed through regimes of freshness.

While the history of chilled and frozen food slowly gains increasing attention in historical and cultural studies, the historical dynamics of the cryopolitical economy in the network society still need to be explored.

Biotechnology, encompassing food production as well as assisted reproductive technology (ART), currently emerges as a most important apparatus (*dispositif*) of governing populations. It should be understood as a means of 'biopower' because it not only contributes to reproducing life but also helps to improve and preserve it. Highly dependent on refrigeration, modern biopower invents a new type of life, which is technologically self-sustained: this is the cryogenic culture. In our paper, we trace the emergence and dissemination of what we call cryogenic life – meaning the ways of producing, distributing, maintaining and dispositioning organic matter via cooling, chilling and freezing. With the introduction of artificial coldness in the late nineteenth century and the expansion of the cold chain, these techniques have become a constitutive element of modern biopower.

I. Introduction to cryogenic culture

In March 2014, HSBC Bank placed advertisements on colossal billboards across dozens of airports worldwide. The posters, depicting a fish with a barcode genetically implanted into its skin, prophesized, 'In the future, the food chain and the supply chain will merge'.[1] While this poster testifies to the current phantasm of global logistics, it conceals that this utopian ideal of the global expansion as well as the indistinguishability of food chains and logistical supply chains has already arrived.

This has also been made possible through a third chain that has presently attained an almost completely global dimension: the cold chain. Countless biotechnologies – from industrial food production to so-called assisted reproduction technology (ART) – have been established as a powerful apparatus or *dispositif* (Foucault 1980) in population development. This can be understood as an expression of *biopower* that not only targets the reproduction of life, but also its protection, expansion, and improvement. As we argue in this article, this modern biopower, categorically dependent upon cooling technologies, generates a new form

1 The placard is available online at: http://www.hsbc.com/~/media/HSBC-com/about-hsbc/in-the-future/pdfs/supply-chain-advert.ashx.

of life, one that we call 'cryogenic life'. This term encompasses the production, distribution, maintenance, and availability of organic material through processes of refrigeration or freezing.

Since the emergence of industrial refrigeration technology and the expansion of cold chains in the second half of the nineteenth century, these processes have become a constitutive element of Western societies. Presently, cryogenic technologies permeate nearly every aspect of daily life: we refrigerate our food, environment, medicines, organs, eggs, milk, sperm, tissue, blood, and much more. The technical processes of cooling, and their inherent ability to freeze living products at their peak – meaning their most valuable and productive form – have become an essential resource of modern population policy. Moreover, these processes lie at the center of fundamental sociopolitical, ethical, and economic disputes, from food scandals to genetic engineering to reproductive medicine. As cryogenic life has become the object of public debates and state regulations, it has moved to the center of what Foucault calls 'biopolitics'. If he designated the origin of this paradigm in the eighteenth century as the ability 'to make live and to let die' (Foucault 1999, 278), then, thanks to refrigeration, it is now increasingly the ability to make live and to *not* let die. Through the search for ever more efficient processes of cryogenic refrigeration of organic material, we are now able to generate a new form of life that can be sustainably preserved for future use by delaying its decomposition through cold storage. This sustainability proves to be more than a question of environmentalism; rather, it concerns the fabrication and preservation of an environment that grants us the power to extend and secure life itself: cryogenic culture.

Cryogenes (from the Greek *Kryos* for cold, and the Latin *generare* for production), or cold-generated cultures, rely on the sociotechnical interweaving of various heterogeneous elements, including thermodynamic aggregates, biological processes, economic structures, and logistical procedures, and even scientific discourses, legal regulations, and social practices. Starting in the nineteenth century, these cultures developed along the cold chain, from animal death to human life. From the beginning, the anthropocentrism of these dynamics was conspicuous. Even where cryogenes have operated in obscurity, their ultimate goal has always been to extend human life, maintain its vitality, increase its productivity, and expand its potential.

Until the end of the nineteenth century, related biopolitical efforts remained concentrated primarily on food production. As these efforts turned to matters of reproduction and the health of individual human bodies, they developed into a comprehensive dispositif of cryogenic culture. Looking more closely at the scientific and technological developments in cold research, two overarching strands emerge: a horizontal line dedicated to the construction of the global cold chain, and a vertical line focused on deploying ever more efficient low-temperature aggregates to reach absolute zero (-273.15 °C). While the horizontal line concentrated on engineering technologies that could solve the biological challenges of keeping food fresh, the vertical was a question of physics, with scientists trying to produce successively lower temperatures approaching the absolute thermodynamic threshold of zero degrees kelvin. While it has always been possible to observe points of contact between these two strands of research, only in the second half of the twentieth century did they come together to form a comprehensive, cryobiological line of inquiry. The history of this interdependence, which we examine in this article, has not yet been thoroughly examined. Thus far in the historical literature on refrigeration technology, these two lines have been investigated separately, in part due to disciplinary constraints (Gavroglu 2014b). They are understood as two different technological styles that follow two distinct lines of inquiry (Dienel 1991a). Here, by contrast, we present and emphasize the early intersections and the lasting interdependence of both lines of research as the foundation for the production of cryogenic life.

In hindsight, two factors proved decisive in the expansion of the horizontal biocentric line, that is, the cold chain. First, the industrialization of meat production in Chicago in tandem with the expanding natural ice industry around 1850 enabled the previously unthinkable mechanization of mass animal slaughter. The ensuing decades witnessed a colossal expansion of cryogenic economics, primarily due to the contemporaneous explosion of infrastructure networks. At the same time, refrigeration began to creep further into other areas of society, from food systems and medical care to urban planning and military procedures. However, as the dependence on cooling procedures grew, the health risks of these methods became clear. Most worrying were the hygienic risks that accompanied the growing pollution of natural ice and the hazards of industrial meat production. In order to safeguard the population from improper refrigeration measures, a biopolitical regime was established in 1900 that strictly regulated the refrigeration industry and encouraged the switch to artificial refrigeration systems.

At the turn of the century, a second factor crucial to the formation of a cryogenic culture emerged alongside the expanded and diversified food supply: cryopreservation. This factor was propelled by the vertical cryotechnical line, in which scientists endeavored to keep both inorganic and organic materials cooled at extremely low temperatures, and to later defrost them with as little damage as possible. In these activities, scientists drew upon eighteenth- and nineteenth-century research, such as the medical applications of liquid gas developed by the Swiss physicist Raoul Pictet. As the cooling industry began to actively support research and development, knowledge of the issue grew, as did the number of applicable patents. Not only did this research advance the development and expansion of high-efficiency refrigeration machines, in the second half of the twentieth century, it led to the formation of a new and flourishing field of cryobiology. Researchers' success in the cryopreservation of sperm found its first use in the cattle industry. New cryogenic blood conservation procedures also enabled the preservation of human tissue for military, ethnological, and medical purposes. As these methods were improved upon and refined during the Cold War, they moved to the center of larger biopolitical efforts, from eugenics to cryonics. With the formation and proliferation of cryobanks in recent decades, a new paradigm of a biopolitical economy has evolved, which has brought an unrestricted control over the *bios* itself within reach.

II. The horizontal freshness regime: The cold chain

1. The industrialization of cooling: The Chicago complex

The search for the origin of the industrial freshness regime inevitably leads to one place: the slaughterhouses of Chicago in the second half of the nineteenth century. Here, within a very short period of time, an incredible apparatus of cold-supported industrial meat production sprang up that radically reshaped the eating habits of entire continents, while also functioning as a laboratory for new techno-industrial processes of food logistics (Brantz, forthcoming; Rees 2013). In Chicago, radical change occurred, both in regard to the production processes that transformed animal carcasses into fresh meat and to the distribution networks that – thanks to technological cooling mechanisms – enabled the transport of highly perishable goods unspoiled to all corners of the country and, eventually, the world.

It is no mere coincidence that Chicago was the breeding ground for the cold chain's horizontal expansion. Founded in 1833 with only 350 inhabitants, the city owes its rapid expansion to its geographic location at the crossroads of numerous trade routes and waterways, as well as its role as a hub in the expanding rail network (Cronon 1992). Chicago quickly grew to become one of the most important logistical intersections in the United States for the trade and transport of grains, wood, and especially meat. The city's population exploded at a rate never before seen. Especially after 1840, the incoming herds of cattle, sheep, and pigs grew larger every year, being driven across the prairie into the city's stockyards, first by cowboys and then later by train. There, the animals were sold, processed, and packaged, before being transported by ship or rail to the market halls of the southern and eastern United States. Soon, vast industrial parks sprung up, whose only purpose was to efficiently kill, butcher, and package animal products on a scale never before imagined. These new factories had little in common with traditional forms of butchery and preservation. Rather, they were the very embodiment of elaborate production complexes, whose extraordinary capacity was made possible primarily by the implementation of new assembly-line technologies and logistical processes. The existing Cincinnati 'disassembly line' method served as a model, but it was critically expanded and perfected in Chicago: using a specially designed conveyor belt, it enabled the routine handling of up to five thousand pigs a day. Following a mechanized procedure of thirteen steps, an entire pig could be completely processed within fifteen minutes: hanging the live hog by its leg, cutting its throat, scalding it, attaching it to a cable, scraping, cleaning, washing, inspection, de-gutting, de-larding, decapitating, splitting, and, finally, chilling (Giedion 1982, 247).

By serializing the killing process and transforming the butchering procedure through the systematic division of labor, the way animal carcasses were converted into food was radically re-engineered. These new methods not only changed traditional conceptions and practices of animal storage and processing, but also fundamentally rewrote eating and consumption practices among Chicago's rapidly urbanizing population (Root and Rochemont 1976). Meat became available at increasingly affordable prices throughout the entire year. Traditionally, animals had always been slaughtered in autumn, when they had reached their ideal weight and when the lower temperatures would slow decomposition. These biological realities concerning the decay of organic matter had long been an insurmountable hurdle in the mass production of meat. The year-round operation of new factory complexes required tremendous overhead, and was only made possible by another innovation: the incorporation of the contemporaneously flourishing natural ice trade. In the eighteenth century, a thriving industry had been built on harvesting the lakes and rivers in the northeastern United States for natural ice. At first, this harvest chiefly supplied the surrounding settlements, but due to increasing demand and improved storage methods, it rapidly expanded outward (Cummings 1949; Whittemore 1994). In 1806, Frederic Tudor, a global pioneer of the ice trade who would later come to be called the 'Ice King', successfully shipped a load of natural ice from Boston to the Caribbean, using a ship with a double-shelled structure and specially isolated cargo bay. The development of this trade route promised enormous profit, and therefore, Tudor next began to build an entire network of ice houses across the globe, stretching from Boston to Calcutta. For this reason he is often credited as the inventor of the cold chain, which at first followed established shipping lanes to the great warm-water ports. Halfway through the nineteenth century, the ice trade had become 'big business' in Western industrialized nations (Täubrich 1991). And, thanks to the new railway connections, enormous amounts of natural ice could now be transported to the slaughterhouses of Chicago.

In the summer of 1859, slaughterhouses began to store their mass-produced meat products in ice-cold storage halls and thereby emancipated their trade from the seasonal rhythms that had determined animal butchery and food culture in the previous millennia. This allowed for enormous growth in the productivity and prosperity of the meat industry. While three thousand pigs could be butchered in a day in Chicago in 1839, thanks to the use of natural ice in factories and storage houses, that same number could now be butchered and processes in less than an hour (D'Eramo 2003, 31–32). This heretofore unthinkable concentration of animal carcasses and the corresponding need for labor in the slaughterhouses fostered rapid population growth, which in turn, also increased the demand for food.

Within this exceptional concentration and coupling of livestock, labor force, capital, and technical apparatuses, the Chicago slaughterhouses became what Mumford (1970) would call a 'megamachine'. With this 'mechanization of death' (Giedion 1982, 270), animal life was progressively reified as an object/thing. Whereas in a traditional butcher shop, the freshly slaughtered animal was still visible to the customer, in the new factories, the killing and gutting processes disappeared entirely behind the complex logistical sequence of refrigeration-supported animal slaughter. What is more, the new, rational, and efficient management procedures in factories coupled with the industrial application of refrigeration enabled the near-total utilization of animal carcasses. Mass production and refrigeration allowed for the use of animal parts whose processing and commodification had previously not been profitable (Cronon 1992, 249–51). Refrigeration technology thus not only helped increase the throughput of meat production, it also encouraged the economic transformation of slaughterhouse waste into profit-making products. For the first time, animal carcasses in their entirety became raw material for standardized, mass-produced goods (Clemen 1923). In this manner, cold preservation created a new form of biological existence that profoundly upset traditional conceptions of life and death (Cronon 1992, 255). As it became possible to delay the natural decomposition of organic substances by means of refrigeration technology, a new understanding not only of freshness (Freidberg 2010) but also of the biological came to the fore. With the help of the refrigeration process, organic matter, whether dead or alive, became readily available.

As the natural ice industry became integral to animal processing, it proved to be a decisive factor for the standardized manufacture of animal products. In order to ship large amounts of refrigerated meat, several biotechnical obstacles had to first be overcome, lest the melting ice impact the form, appearance, and taste of the unpackaged meat. Beginning in 1865, numerous engineers, entrepreneurs, and inventors began working feverishly to develop new refrigeration procedures for preserving meat for national and international transport, by both land and sea. Impressive sums of money were even offered as prizes for patentable solutions (Rees 2014, 255). The breakthrough occurred in 1880, when the entrepreneur and master butcher Gustavus Swift successfully developed and implemented mechanically refrigerated train cars (Giedion 1982, 250–51). With this invention, it became possible to ship mass quantities of fresh beef over large distances, even in the summer months. This biotechnical assemblage of conveyor belts, railways, ice, and meat proved so influential that, in hindsight, it could be considered the decisive momentum behind the evolution of the global cryogenic economy. Within a short period of time, other Chicago entrepreneurs also began to use this technology and expedite the expansion of the cold chain. It soon stretched across the entire North American continent, reaching the colonies and finally England, where it eventually dominated their meat market (Rees 2014, 258).

Of course, not everything in this story went as smoothly as thus far presented. The meat packers of Chicago were confronted/challenged by those in support of traditional butchery. These butchers – under extreme financial pressure – successfully mobilized public distrust of the frozen commercial products, claiming that they were unnatural and hazardous to human health (Cronon 1992, 235). This public mistrust turned around instantly once the meat packers drastically cut their prices well below that of the local butchers, began to unload their goods directly off the refrigerated trains, and distributed the meat to customers appetizingly, draping it on large blocks of ice. Facing these brutal price politics, dissenting butchers were forced to submit to unfair contracts, in which they had to stop their own slaughter business and could only offer meat products from Chicago (Cronon 1992, 235ff; Rees 2013, 91).

The notable economic aggressiveness of the Chicago chilled meat industry is inherently thermodynamically contingent. The enormous quantities of meat could be chilled in order to maintain their freshness, but they could not be stored for long: the meat had to be sold – at any cost – to consumers as quickly as possible. As the coupling between thermodynamics and high finance destroyed traditional butchery, the new biocentric refrigeration infrastructure established a powerful and efficient economy. At the turn of the century, this new economy was able to provide fresh meat to the entire US population as well as to numerous other countries.

2. The rise of the cold chain as second-order infrastructure

The impressive expansion of the cold chain was substantially based on its status as a second-order infrastructural complex. While the chain was built upon already existing infrastructure, it also greatly expanded this infrastructure's reach and complexity. This interdependency was already evident in the development of fresh meat logistics in Chicago. American refrigerated meat production began to centralize when Chicago's nine largest railway barons joined with parts of the Chicago Pork Packers' Association to form the Union Stock Yard and Transit Company (Cronon 1992, 210). Well into the early twentieth century, the cold chain grew under the aegis of meat production, built upon a foundation of mass slaughter, refrigerated trains, and price dumping. A network of ice houses, using sawdust as insulation, was erected along major railway lines in order to replenish the refrigerated rail cars (Rees 2013, 90ff). Animal processing centralized around the exchange building of the Union Stock Yard. This building housed a bank, which already in 1860 was processing transactions of a half-million dollars on a daily basis, as well as numerous telegraph offices that collected news and meat prices from every corner of the planet (Cronon 1992, 211f). With the help of this multilayered infrastructural complex, the Chicago meat industry also soon tapped into the growing agricultural market. They were then, however, quickly squeezed out, after Union Pacific and the Southern Pacific Railroad formed a new rail network, the Pacific Fruit Express. The Pacific Fruit Express established a powerful network of ice factories and delivery agents across the country in order to replenish the refrigerated freight trains traveling from California eastward. In 1924, the railway was one of the largest manufacturers of ice in the entire country (Rees 2013, 96f).

Alongside the growing international meat trade, the burgeoning yet plentiful import of southern fruit into the northern hemisphere also helped advance the maritime construction of the cold chain. Although Frederic Tudor built the first major network of ice houses along the main shipping routes in the first half of the nineteenth century, by the 1870s, aspiring fruit-trading societies further developed the coordinated logistics involved in cultivating, harvesting, and transporting perishable goods via refrigerated ships and train lines. New geographies for business arose, including the so-called banana republics (Guatemala, San Salvador, Honduras, Nicaragua, Costa Rica, and Panama), which continue to supply two-thirds of the worldwide banana supply today (Tschoeke 1991a, 131). On the one hand, an efficient cold chain can be understood as a set of logistical and technical innovations that enables the transport of the correct amount of perishable goods to the correct place at the correct time, and for the best price. On the other hand, it is also the biological contingencies of perishable organic substances themselves that necessitated the implementation of these inventions to assure 'just-in-time' delivery. These connections and synchronizations of diverse infrastructure first affected/shaped/transformed ports and shipping lines, then railways and telegraph networks shortly thereafter. After the First World War, they also impacted the electrical grid and the road network, and then finally airplanes, satellites, and digital networks.

Particularly significant for these developments is the fact that then, as now, the construction of the cold chain was undertaken by large-scale infrastructure companies. This is partially due to the enormous costs involved in the chain's construction and management. However, from the very start, there were also other inherent functional reasons for these entanglements, many of which became especially clear following the transition from natural ice to manufactured ice beginning in the year 1900. This capital-intensive restructuring of the 'freshness regime' touched upon a complex constellation of issues, the biopolitical dimensions of which are discussed below. From an infrastructural point of view, the next step was the installation of a large-scale power grid. Already at the height of the natural ice trade, it was evident that a large amount of energy was necessary to ensure the systematic coupling of the cold chain with transport and telecommunications infrastructure. Ice was first delivered by firms that had specialized in coal trading, as the seasonal need for cooling agents skyrocketed at exactly the same time as the need for heating material disappeared, and vice versa (Rees 2013, 79). The switch from natural to manufactured ice use was linked to seasonal rationales; in summer, there was little demand for electricity, and during this time, ice manufacturers were able to use leftover power to earn enormous profits. For some electricity companies, ice production yielded greater returns than the electricity business itself. Although energy costs were the largest expense in ice production, electricity companies could cover these costs using the overcapacity produced by the plants during summertime (Rees 2013, 53).

In the 1920s, when electrical refrigerators were first introduced, the large energy companies, especially General Electric, also actively participated in the market introduction of small refrigeration appliances. Given that a refrigerator was responsible for half of an average household's energy use, these appliances promised large profits for energy providers (Freidberg 2010, 39; Rees 2013, 145–46). However, the existing power supply network was not yet sufficient for the nationwide use of these appliances: the infrastructure for power provision had to be decisively improved and individual houses had to be connected to the grid. As these two issues improved, electric refrigerators began to be produced en masse. For this, the already developed assembly line method (perfected by the auto industry) proved to be an ideal process. In 1918, General Motors brought the Frigidaire model to market. As a promotional stunt, in 1931, the company gave their millionth factory model of their successful Monitor Top refrigerator to Henry Ford (Dienel 1991a, 102). Thus, beginning in the 1950s, once private households nationwide were connected to the power grid, and Fordist models of mass production and consumption had overtaken as the socioeconomic norm, small cold appliances found their way into almost every middle-class home (Giedion 1982). During the Cold War, on both sides of the Iron Curtain, the refrigerator became a standard piece of kitchen equipment, and refrigerator ownership defined one's self-image as a member of an industrial society. Only since 1984 has a refrigerator no longer been considered a luxury item by state welfare agencies in (West) Germany (Hellmann 1991).

After electric refrigeration equipment had firmly infiltrated both private households and supermarkets, a steady stream of refrigerated trucks on a well-developed road network was required to deliver perishable goods from transport hubs at seaports and airports to well-stocked grocery store shelves. Now that the cold chain extended into private homes, the 'new economy of cold' (Watkins 2002) enabled the effortless continuation of storage and provision of fresh food into the private realm. The growing internationalization and mechanization of food did not only change daily diets (Root and Rochemont 1976; Ogle 2013), it also established a new cultural time-space assemblage, in which the availability of groceries was no longer limited by seasons and climate zones. This assemblage necessitated a global network of cold spaces: the cryosphere of the network society. The global refrigeration network, a second-order infrastructure and a perma-cooled 'space of flows' (Castells 2005), is now monitored in real time by computers and satellites. If the early obstacles of the cold chain largely were the difficulties of integrating cooling machines into the transport infrastructure (Tschoeke 1991a), contemporary issues include the implementation of digital information technologies and radio-frequency identification (RFID) chips (Emond 2008). Thanks to the digital interdependency of multiple infrastructures, the computer-steered and container-based logistics of today's 'cold chain management' enables the near risk-free circulation of organic substances. On the foundation of the global cooling networks, whole new topologies and trade opportunities emerged, as well as an unprecedented availability of organic materials that could be used for either food or medicine. The cold chain proved to be the fundamental space-time dispositif of cryogenic culture.

As refrigeration technology evolved into an unavoidable element of modern society, a number of risks also arose. Today, long after the global cold chain has been linked and perfected into a technogenic cryosphere, these dangers only become apparent when this infrastructure fails or breaks down (Graham 2010). This was particularly evident in the aftermath of Hurricane Katrina in the southern United States in the summer of 2005. A decontamination team had to work for six weeks to remove twenty-six million pounds of rotten meat from New Orleans Cold Storage, as four weeks without power turned the company's storage halls into a verifiable pool of toxic waste (Twilley 2014). The refrigerated storage units contained not only meat but also vegetables, fish, toiletries, and medicines, all that we have long since deemed necessary for daily life. Today, the uninterrupted functioning of the cold chain in industrial nations is strongly enforced by food supply and hygiene authorities. All that circulates through the cold chain is the object of biopolitical regulation, because refrigerators and refrigerated goods have become part of a larger societal discussion on the nature of the public good.

As we discuss below, the biopolitization of refrigeration first emerged around 1900. During this time, a dense network of state regulations and controls began to develop, as refrigeration technology had become recognizably indispensable for social progress. The possible risks and benefits of biocentric refrigeration technology for the general public remains deeply contested. The international course of this controversy, bouncing between businesses, scientists, politicians, and medical doctors, has led to the creation of complex biopolitical actor-networks. Their dynamics determine the implementation and enforcement of cold chain infrastructure, as well as its regulation of the socialized *bios*. Here too, however, the march of progress has been anything but easy. These tensions nonetheless ultimately led to a growing demand for refrigeration in even more aspects of daily life.

3. The biopolitization of artificial cold

By 1890, it had become apparent to North Americans that refrigeration technology had far exceeded its original promise. This technology had established itself in countless spheres of society and had gained a central significance for human well-being. As the industry journal *Ice and Cold Storage* excitedly reported in July 1898, refrigeration was not just a matter of modern living, but also of modern warfare:

> The initial application of refrigeration was devoted to the importation of frozen and chilled meat from all parts of the globe, to meet the constantly-increasing demand of our ever-growing population. From this commencement the freezing industry has grown apace. Refrigerating machines of various kinds are now extensively used for preserving all kinds of dairy produce; for brewery purposes; fruit importation; bacon curing; India-rubber manufacture; natural-ice skating rinks; preserving fish, poultry and game; chocolate cooling; gunpowder works; smokeless powder factories; private

> mansions, hotels and asylums; and last, but by no means least, on mercantile ships of all nations and men-of-war of our own and other Powers. (cited in Rees 2014, 264)

In this over-the-top mixture of advertisement, social diagnosis, commercial calculations, and great promises for civilization, we find a new productive understanding of the growing significance of refrigeration technology for 'our ever-growing population . . . and other Powers', as well as a new relationship between life and death. A fundamental reorientation of this relationship was already made clear in the controversy over Chicago's chilled meat, which despite its wholly different production methods was now equaled to fresh food, even after traditional butchers denounced it. 'Fresh' was now also taken to mean meat slaughtered days previously, so long as it had been sufficiently chilled.[2] However, what 'sufficiently' meant precisely was now a criterion to be decided through years of experience and heated debates among engineers, industrialists, traders, medical doctors, consumers, and, eventually, state agencies.

Around 1900, as various actors attempted to improve nutritional practices, the very consequences of refrigeration technology on human health became a central topic in biopolitical debates. It was crucial to protect the population from the dangers of improper refrigeration, and to put the vital powers of cold to their best possible use. Soon the conversation extended beyond food. Beginning in the middle of the nineteenth century, medical doctors, social reformers, and urban planners developed a greater interest in the health benefits promised by artificial cold. As early as 1806, Tudor was convinced that the import of natural ice to the tropics would provide help to cool – and thereby heal – those suffering from yellow fever (Korneffel 2008). Similarly, the supply of natural ice to civilian and military hospitals in North America and Europe promised faster recoveries and decreased mortality rates. Indeed, hospitals were the first major users of mechanical refrigeration machines. Already in 1840, Dr. John Gorrie managed to develop a simple air-conditioning system for medical establishments (Hård 1994, 57). In 1864, *Scientific American* published a well-received article advocating for the blanket installation of air-conditioning systems in clinics and hospitals (Nagengast 1999, 50). Similar arguments were soon made for other public buildings, such as theaters, churches, and parliaments.

2 For a detailed investigation of the historical displacement of the category 'fresh' using perishables as the investigatory focus, see Freidberg 2010.

Already at this early stage, refrigeration was expected to improve human health not only indirectly by chilling perishables but also directly by acting upon human bodies themselves. This soon also applied to the deceased. The rise of funeral parlors beginning in the 1870s can largely be attributed to the installation of refrigeration machines, which could calm social panic about being buried alive, as suspended animation was frequently mistaken for death (Brantz, forthcoming; Murko 1991).

The growing cold infrastructure was not only a blessing for the food production and medical care of the civilian population, but was also equally crucial for war technology and military logistics. For example, natural ice achieved a central strategic role in military hospitals during the American Civil War. After the massacres of the Seven Days Battles in the summer of 1862, Confederate newspapers with the desperate cry-for-help headline 'Send ice!' were distributed at large.[3] When the frontlines definitively cut off the Confederate states from natural ice supplies from the North, attempts were made to compensate with mechanical ice-makers, which then massively sped up the machine's refinement.

Seeing the success of artificial refrigeration techniques in the treatment of the war wounded, demands were made to deploy the technology against the catastrophic hygienic conditions in rapidly urbanizing metropolises worldwide. If the expansion of the cold chain definitely encouraged the growth and prosperity of nineteenth-century cities, then the downsides were about to become apparent. The massive overcrowding of urban inhabitants in tenements and slums led to epidemics, catastrophic mortality rates, and often-violent social unrest (Boyer 1992). Pacifying these sections of society and integrating them into larger economic and political structures became a biopolitical obligation of the highest order. Foucault had already emphasized the importance of this mobility paradigm for the liberalization of the social order in the eighteenth and nineteenth century (Foucault 2006a, 37). The demands of social reformers for better housing and access to infrastructure culminated in this paradigm

[3] 'We renew our solicitations for ice on behalf of the unfortunate wounded. The repulse of the Yankees has given us access to a large portion of the lower country, in which there are numerous ice houses packed with this indispensable. We ask, in the name of our suffering wounded, that these supplies be immediately forwarded to the city, and distributed ad libitum to every hospital. Much misery may be alleviated and numbers of lives saved by its use. Let this be done at once. If those who claim to be owners of the ice in the counties below will not disgorge at the appeal of patriotism, let those who are in authority take it, nolens volens' (*The Daily Dispatch* 1862).

with their cry for 'Fresh air, fresh water, fresh food!' (Joyce 2003). Its implementation resulted in the creation of new sanitation systems, new forms of building in overcrowded cities, as well as the intensive expansion of the cold chain for the protection of the food supply. In the course of these changes, the food supply of urban populations became increasingly dependent on far-away resources. This in turn, required the expanded construction of ice houses, which were now built in a monumental architectural fashion that symbolized and celebrated the civilizational achievements of the cold chain (Tschoeke 1991b). The demand for ice also increased dramatically in the last decades of the nineteenth century, creating stratospheric growth rates for the natural ice industry. In 1880, annual ice consumption in the United States had already reached five million tons, half of which disappeared into the iceboxes of private households (Rees 2013, 23; Täubrich 1991, 58).

This moment marks the high point of the natural ice industry, as well as the start of its downfall. With the popularization of germ theory and the growing pollution of lakes and rivers caused by industrialization and urbanization, natural ice harvested from public and private water sources came under heightened scrutiny as a hygienic danger and as a biopolitical object for new regulations. Until this point, the presumption stood that freezing destroyed the bacteria and toxins in water, and as such that natural ice was self-cleaning (Rees 2013, 61). By the end of the nineteenth century, this conviction began to weaken, and fears and uncertainty took its place in the minds of consumers. Soon politicians and social reformers began to debate the risks of natural ice and demanded legal regulations and controls. In 1893, the medical doctor William Blackwood's widely read condemnation of the myth of self-cleaning ice cast serious doubt on the natural ice industry (Rees 2013, 63). The biopolitical discourse on the dangers of natural ice, and the safety promised by technological progress, led to the rise of an ostensibly hygienic mechanical ice production. As inventors and engineers in North America, and especially Europe, succeeded in stabilizing the efficiency and reliability of mechanical refrigeration machines, natural ice was completely phased out of the food industry.

The final moment came in 1901, when a typhus epidemic broke out in – of all places – a hospital, the St. Lawrence State Hospital in New York state, and which could be definitively traced back to the consumption of natural ice. For the first time, it was publicly understood that bacteria could survive in natural ice and that even chilled perishables could contain a life-threatening danger. As a result, the switch to manufactured ice became an urgent biopolitical imperative, especially as industry-caused environmental pollution surged dramatically. To protect the population from these industry-induced risks, state authorities began to sign increasingly strict regulations into law. In some parts of the country, the harvest of natural ice was even outlawed (Anderson 1953, 111).

The risks of inappropriately chilled meat also became apparent in the provisions for US soldiers. In 1898, a scandal erupted in the US Congress, when hundreds of tons of rotten chilled meat from overseas caused a massive health and supply crisis on the battlefields of the Spanish-American War (Rees 2014, 251).

With the signing of the Federal Meat Inspection Act in 1906, the US government began to widely monitor the production and sale of perishables, with a particularly close eye kept on the Chicago slaughterhouses. Upton Sinclair's whistle-blowing book *The Jungle* from the same year exposed the unhygienic and inhumane working conditions in Chicago. By forcing the situation to a head, the book directly influenced the creation of the act.

The growing problem of natural ice hygiene forced stricter biopolitical regulations that, in turn, attacked both the purity of the cold chain and the supervision of meat production. While the transition to manufactured ice held the promise of *clean* refrigeration, the regulation of the cooling trade was supposed to make refrigeration *safe*. As a result, beginning in 1900, hospitals, alongside food processing plants, breweries, and container ships, all intensified their efforts to transition from natural to manufactured ice. End consumers remained dependent on natural ice until private households were electrified. However, consumer awareness of the dangers of natural ice was now firmly established. A demand was made for greater food security on behalf of consumers, who not only legitimated the biopolitical regulation and control of the refrigeration industry but outright demanded it.

In parallel, the question arose: should perishable food products be cold-preserved at all, and if so, how? This became one of the most important (and now completely forgotten) controversies of the Progressive Era (Rees 2013, 99–100). In order to decide this question once and for all from a scientific perspective, Dr. Harvey Washington Wiley of the Bureau of Chemistry at the US Department of Agriculture conducted a series of experiments in 1910, with which he verified the utility of refrigeration technology for the preservation of perishable food products (Rees 2013, 100). While Wiley's results and technical progress contributed to the cleanliness and safety of the cold chain, it fell to political institutions to guarantee it. Beyond questions of food safety, the issue of food waste also became an argument for the state-sponsored construction of market cold storage, which were supposed to fill gaps in the cold chain. This public appeal for an organized and hygienic system for the circulation of chilled organic substances formed a sustained regime of cryogenic biopolitics that is still effective today. In this way, people of all social classes gained access to healthier and cheaper foodstuffs, thereby increasing their life expectancy and productivity.

III. The vertical freshness regime: Low-temperature research and cryobiology

While American entrepreneurs and engineers worked to develop the cold chain, the European interest in mechanical cooling around 1900 focused on researching – and creating – increasingly low temperatures. Until recently, these disparate goals were seen as the expression of two different scientific approaches: whereas the Americans were motivated by practical concerns, the Europeans were more interested in cultivating theoretical insights offered by the technical production of extremely low temperatures (Dienel 1991a). This notwithstanding, since their invention in the 1880s up until 1930, German refrigeration models were the most efficient cooling appliances on the market (Radkau 2008, 168), the most successful being a system designed by Carl Linde (Hård 1994). These efficient devices allowed for the continual expansion and optimization of the cold chain, which was then undergoing electrification. The German low-temperature researchers, however, had little interest in this practical application. While European cooling researchers proved to be surprisingly enterprising, their interest nonetheless lay first and foremost in thermodynamic problems; the development of better cooling systems was only an epiphenomenon. These theoretical insights into the nature of thermodynamics are of systematic, constitutive importance to the study of low temperatures, and the race to reach absolute zero. The attempts by researchers to reach this point led to a series of Nobel Prize-winning discoveries and theories in the fields of gas liquefaction, superconductivity, and quantum theory (Mendelssohn 1966). At first a purely theoretical and experimental project, this research eventually yielded a great practical use: low-temperature facilities for the industrial production of liquid gases, the so-called cryogens. Because these cryogens were at first irrelevant for the cold chain, both strands of cooling research (beyond their technical-historical connections) had been until this moment investigated separately. Low-temperature technology was deemed 'the younger sister of ordinary refrigeration technology' (Dienel 1991b:88), where 'ordinary' refers to the by then commonplace appliances used to keep groceries fresh and rooms air conditioned. Even recent publications within the volume *History of Artificial Cold* (Gavroglu 2014b) maintain this dichotomy.

When we refer to the two 'styles' of cold research as 'horizontal' and 'vertical' strands in the development of refrigeration technology, we are also orienting ourselves along this same division; however, we do so here only to highlight the historical and systematic connections present between them. In so doing, we demonstrate that even from the beginning these strands often intersected, and that, especially after World War II, this interdependency intensified even further. In the process, this connection encouraged numerous developments, qualifying it as a fundamental biopolitical dispositif of cryogenic culture. The precise meaning of this will be clarified below, when we turn to discuss the biocentric tendencies of the vertical line. In so doing, this article will demonstrate that while 'in the USA, the intersection of refrigeration and organic matter had been the research emphasis since 1880' (Dienel 1991a, 106), low-temperature research coalesced during the Cold War under the rubric of cryobiology (Parkes 1964; Smith 1970; Leibo 2013). This still nascent, and yet already tremendously successful branch of science investigates the impact of extreme cold on organic substances. The emergence of cryobiology marks a historical turning point, at which both lines systematically and permanently fused, with the result that today cryobiological products and perishable foodstuffs both circulate on the global cold chain in similar quantities.[4]

1. The early history of cryobiology

While the first successful medical advancements of cryobiology were squarely the result of twentieth-century research into low-temperature physics, interest in the behavior of living and dead organisms under the influence of extreme cold was sparked as early as the early modern era. Already the English philosopher, scientist and statesman, Sir Francis Bacon had envisioned enormous refrigeration facilities for cooling uses: 'Coagulations, Indurations, Refrigerations, and Conservations of Bodies' and 'Towers, according to their several heights and situations, for Insolation, Refrigeration, Conservation' (Bacon 1669, 23). From a preservation standpoint, Bacon himself, shortly before his death, stuffed a chicken with snow to ascertain if the cold could conserve the meat as well as salt might (Shachtman 1999, 22–23). The medical effects of the cold were of particular interest to the philosophically minded Lord Chancellor, which he pursued in his *History Natural and Experimental of Life and Death or Of the Prolongation of Life* (Bacon 1669).

[4] This insight was sparked by a group excursion to the Perishable Center Frankfurt during the Infrastrukturalismus der Frische workshop at the Technische Universität Darmstadt, November 2013.

Similarly, Robert Boyle, in his *The Prolongation of Life* from the 1660s, wrote a veritable scientific 'wish list' that included: 'The Recovery of Youth', 'Great Strength and Agility of Body', and 'The Cure of Diseases . . . by Transplantation' (Alleyne 2010). During this period, Boyle published his results in *New Experiments and Observations touching Cold or An experimental History of Cold* (1665), which, alongside the *Prolongation of Life,* are today considered the historical precursors to current cryobiological research (Christopoulou 2013). A century later, in 1790, the Italian Jesuit priest and university lecturer Lazzaro Spallanzani studied the effects of cold on birds and reptiles (Gosden 2011, 264; Thomson 1964, 202). He discovered the preservation effect of snow on germ cells and anticipated the future possibility of artificial insemination (Thomson 1964, 202; Gosden 2011, 264). In light of their biopolitical uses, the Italian doctor, ethnologist, and pathology professor Paolo Mantegazza built upon Spallanzani's experiments in the mid-nineteenth century. He suggested to not only freeze the sperm of horses and bulls but that of soldiers as well: 'It might even be that a husband who has died on a battle-field can fecundate his own wife after he has been reduced to a corpse and produce legitimate children after his death' (quoted in Clarke 2006, 1649). Mantegazza implicitly understood that the eventual human application of animal research would have its greatest potential within the context of military conflicts and population growth more generally.

These historical predecessors have been regularly cited both by the pioneers of twentieth-century cryobiology as well as the discipline's current practitioners in order to place themselves on a long scientific trajectory of great biopolitical relevance (Polge, Smith, and Parkes 1949; Bunge, Keettel, and Sherman 1954; Smith 1961). As the prominent cryobiologist Stanley Leibo (2004, 353) stated, 'It is clear from such accounts from the past several centuries that people have long been interested in the possibility of controlling reproduction by use of low temperatures'. However, before cryobiological research could have broader social relevance, certain technical prerequisites needed to be fulfilled – namely, the successes of research on low-temperature physics and its subsequent utilization for medical purposes. Primary among these technical advancements was the liquefaction of gas and the invention of attendant technology for the isolation, measurement, and regulation of extreme cold. Low-temperature biological research was therefore just as significant as low-temperature research from the field of physics. In this way, Swiss physicist Raoul Pictet, who in 1877 first successfully liquefied nitrogen (Mendelssohn 1966, 40), also invented 'frigotherapy': a therapy by which a diseased human body was briefly subjected to extreme temperatures of approximately -100 °C by means of a liquid gas-based 'cold well'. Pictet himself supposedly healed his own stomach problems in this manner (Sloane 1900, 338–41). Professional circles were beguiled, and frigotherapy soon caught on as a cure-all for innumerable illnesses. Liquid gas was soon employed in surgical environments as a local anesthetic and as a dermatological cure (Kavaler 1972, 147f; Sloane 1900; Nagengast and Kraus 2005). Pictet's medical utilization of cooling technology attests to the fact that even from the beginning, the vertical strand of cold research was directed toward the biological and anthropocentric, with the intention to improve and extend human life.

This same telos can also be found in the efforts and accomplishments of the French physicist and doctor Jacques-Arsène d'Arsonval, who in many respects is also celebrated for his biopolitical applications of cold research. In 1882, d'Arsonval became both the director of the laboratory for physics and biology at the Collège de France and the mayor of his hometown of La Porcherie, while simultaneously beginning work that blended the fields of physics, medicine, and politics (Justesen and Guy 1985, 112–13). Soon thereafter, he also became president of several high-ranking specialist societies in biology, engineering, physics, and electrotherapy. He also founded the International Institute of Refrigeration (IIR), a society organized after the first international congress for refrigeration technology, which was held in 1908 at the Sorbonne in Paris. From a historical perspective, this meeting of lead scientists from the field of low-temperature research with representatives from the cooling industry was a decisive moment in the convergence between the horizontal and vertical strands of refrigeration. As a result of the congress, the International Association of Refrigeration (IAR) was founded in 1909. The IAR was one of the first-ever international corporations, which, under state pressure from the US Federal Meat Inspection Act of 1906, negotiated the rules for the standardization of the production and transportation of cold and frozen goods. In the process, technical and hygienic questions were negotiated alongside legal and economic interests, promoting the IAR to an influential biopolitical institution. Founding members included high-ranking industrialists, politicians, and researchers such as Heike Kamerlingh Onnes, a leading low-temperature physicist, and Charles E. Guillaume, director of the International Bureau of Weights and Measures (Papanelopoulou 2009). A principal purpose behind the corporation's formation was the financial gains foreseen by an intensified commercial use of refrigeration (Gavroglu 2014a, 4). In light of these expectations, huge sums of money were invested in vertical refrigeration research.

The low-temperature lab started by Onnes at the University of Leiden, which later came to be called 'Big Science', profited immensely from IAR-dispensed grants (Delft 2014). D'Arsonval's physics and biology laboratory, where he conducted low-temperature research on biological substances (Papanelopoulou 2009), also received considerable financial support from the refrigeration industry. The enormous advances in cold research also rested upon the application of a newly developed tool, the cryostat. The invention of this vacuum-sealed thermal container is usually ascribed to James Dewar who perfected the device; Dewar was

Onnes' Scottish rival in the race to absolute zero. Nonetheless, five years before Dewar's public presentation of his famous invention, d'Arsonval had already reported on such a device (Mendelssohn 1966, 57), which then motivated d'Arsonval to build up the International Institute of Refrigeration to become one of the leading research institutes in the world. The cryostat also proved instrumental in the rise of manufactured ice into a billion-dollar industry (Justesen and Guy 1985, 113). Through the use of cryostats and cryogens, which could now be mass-produced thanks to Linde's machines, refrigeration once again began to make rapid progress. The 'big science' of deep-freeze research and the 'big business' of the cooling industry had united – with wide-ranging economic, scientific, and biopolitical consequences.

In 1924, at the 4th International Congress of Refrigeration, where d'Arsonval was expected to announce a process for the cryopreservation of vaccines, a correspondent for the *Journal of the American Medical Association* excitedly announced that 'many of the subjects are of medical interest. The organizers of the congress desire to get in touch with members of the medical profession who would be willing to contribute papers on the uses of artificially produced cold with regard to medial research and practice' ('International Congress of Refrigeration' 1923, 1704). Nonetheless, the correspondent for *Nature* magazine found the small number of contributions by biologists at the congress rather disappointing. What he did find impressive, were the fundamental biological questions raised by the rapid pace of progress in refrigeration technology, especially the potential of cryogenically storing organic substances (Griffiths 1924). Indeed, it was precisely these possibilities that became the leading lines of inquiry for cryobiologists in the ensuing decades. One central question also began to fascinate the general public: to what extent was it possible to freeze and defrost organisms without harming or destroying their elementary vitality? What in horizontal refrigeration research within the context of the food industry was considered a problem of dead bodies, in the form of meat products and other perishables, became in the vertical line a question of how to maintain living materials through cryopreservation. In other words, how could refrigeration extend the living process?

2. The rise of cryobiology

Building upon the early insights regarding the astounding hardiness of deep-frozen microorganisms, Jesuit priest Basile Joseph Luyet began to systematically expand the field of cryobiology in the 1930s. Luyet, a Swiss emigrant, biology professor, and doctor of physics, reviewed all scientific publications on biological cold experiments in the last two hundred years with Sister Marie Pierre Gehenio, before they finally published an expansive study, *Life* *and Death at Low Temperatures* in 1940 – a work that quickly became the standard bearer of the field. Luyet's major contribution was the development of a cryopreservation process that prevented the formation of ice crystals, which can destroy newly frozen cells (Schmidt 2006; Gosden 2011). With this process, called 'vitrification', Luyet also developed the first theoretical treatise on cryopreservation, which described a state of existence different from death in its wondrous potential to suspend, and then reanimate, life functions after defrosting. Luyet called this state 'latent life' (Luyet and Gehenio 1940, 255).

Already in 1948, Parkes and his research team in London discovered the cryoprotective effect of glycerol on sperm, and, with that, a protective agent against frost for germ cells (Polge et al. 1949). Remarkably, one application was especially well-suited to the implementation of this technique: 'Alan Parkes was acutely aware', his former colleague Christopher Polge (2006, 271) recounted, 'of the growing importance of artificial insemination in cattle breeding, and he arranged for Audrey Smith and me to undertake some work on bull semen at the laboratory of his old friend S. S. Folley at the National Institute for Research in Dairying, close to the Reading A[rtificial] I[nsemination] Centre'. Parkes convinced the British Agricultural Research Council and the Medical Research Council to finance a mobile laboratory, which later became the first facility to successfully store frozen bull sperm. As a result of these new processes, by the end of the century the artificial insemination of cattle had switched to exclusively using deep-frozen sperm. The process yielded a great rate of impregnation as well as tremendous profits. Soon artificial insemination would also be used in human patients in the United States and Britain (Polge 2006, 272).

In light of these impressive results, attention soon moved to another bodily fluid: blood. In 1948, Luyet was invited to a conference at Harvard on blood conservation, put on by the National Research Council, the National Institutes of Health, the Red Cross, and notably, the United States military (Schmidt 2006, 243). When Luyet started to adjust the process of vitrification to work with blood, cattle remained his primary research subject; however, this time, he was not dealing with the beginning of their lives, but rather the very end. 'Days would begin', a colleague later recounted, 'with early morning trips to a nearby slaughterhouse to catch blood spurting from the slit throat of a cow swinging from a huge hook' (Schmidt 2006, 243f). The flow of blood from the animals slaughtered on the disassembly line now became the object of a systematic cold treatment. In 1951, both Luyet and Parkes were invited to a symposium on cryobiology at the Royal Institution in London (Gosden 2011, 265). That same year, Parkes's team successfully employed the new antifreeze agent glycerol in the first transfusion of red blood cells in rabbits (Schmidt 2006, 244; Parkes 1956). At the Third International Congress on Animal Reproduction, news of this success was met with approval not only by animal breeders but also by government officials, health organizations, and the military. There was great hope for the implementation of these findings for human medicine.

During World War II, the US Army had already gained valuable insights into the manufacture of blood storage, and had created the first cold chain for cryobiological products in order to treat wounded soldiers. In order to supply US military hospitals in the Pacific with fresh blood, huge quantities were packed in ice in Oakland, then transported by way of Hawaii to the battlefields (Radin 2013, 489; Kendrick 1964; Turner 1970). Thanks to expertise gathered as far back as the Civil War, military cooling logistics had narrowed the turn-around time on manufacturing blood bottles from creation to transfusion to less than seven days (Starr 2000). Whereas blood used to flow out of the cold chain, in the postwar years, its flow was reversed in a remarkable way. Within the nascent International Biological Program (1964–1974) at the World Health Organization (WHO), a new research group was founded, which would eventually become the Scientific Group on Research in Population Genetics of Primitive Groups (Radin 2013, 491). At the WHO's instigation, the military cold chain was used to take blood samples from indigenous groups on the Pacific Rim. These samples were sent to newly created biotech research centers where the genetic analysis of the blood was made permanently accessible. The globally networked Scientific Group considered the biomaterial collected from these isolated 'primitives' as a priceless resource for human genetic research, and one that had to be secured at any cost. Great haste was necessary, for it was only a matter of time before this precious gene pool, still untouched 'in the wild', would be contaminated by encroaching Western civilization with its attendant ills of sexual mixing and environmental pollution.

Albert Damon, an anthropologist and physician at Harvard, learned of these ideas in 1964, and decided to lend his support to the WHO project (Radin 2013, 491). He began to search for a reliable method to cryogenically preserve human blood. Upon discovering that animal breeders were the most experienced in the technical application of cryobiological insights, he turned to the American Breeders Service for assistance.[5] From this association, Damon

5 For more information on how glycerol-based cryopreservation of sperm revolutionized international animal breeding, see Parkes's colleague, Audrey Smith, *Biological Effects of Freezing and Supercooling* (1961).

learned how to safely process deep-frozen bull sperm in large quantities. He learned where to source liquid nitrogen from the engineers at the Linde Division of Union Carbide, a partner society of the American Breeders Service (Radin 2013, 497). As a result of his successful application of these processes and products in the collection and conservation of indigenous blood samples, Damon was accepted into the WHO research group, which was then renamed The Working Group on Research in Human Population Genetics. The United Nations' new interest in the use of cryobiological methods in medical and food provision became clear in 1948 with the establishment of an expert commission on deep-frozen food, whose express purpose was to uncover the potential of this technology to end world hunger (Thoms 2014, 208). In 1962, Parkes also began to engage more closely with the WHO working groups.

These developments make clear how the collective interest in the cryopreservation of human tissue and animal substances in the second half of the twentieth century gave rise to the formation of a global actor-network of scientists, military personnel, engineers, industrialists, corporations, and politicians. In the creation of this network, the horizontal and vertical strands of biocentric refrigeration research were woven ever more tightly together, laying bare the growing biopolitization of cryogenic life. Finally, the dangers and end-of-days specters of the Cold War made the applications of cryopreservation not only possible but vehemently necessary. As the following section demonstrates, the goal of cryotechnology would eventually become more than simply increasing the growth and productivity of human populations, but move in the direction of improving individual subjects as well.

3. The biopolitization of cryobiology

In the formation of the cryogenic biopolitical regime, Parkes was once again a leading contributor. Soon after the end of WWII, he was active as a board member of numerous animal husbandry and reproduction societies; he also founded several leading journals, among them the *Journal of Reproduction and Fertility*. During this period, he also became interested in questions of population control and birth control. In the 1940s, he became a member of the Biological and Medical Committee of the Royal Commission on Population and later received support for his research from the Family Planning Association. Beginning with Parkes's engagement at the WHO, the organization began to strengthen its emphasis on issues related to birth control. In 1968, Parkes founded the *Journal of Biosocial Science* and was elected president of the Eugenics Society, which was one of the first societies to explore the potential of cryopolitical population policy (Polge 2006, 279f). Carlos Patton Blacker, secretary of the Eugenics Society and former advisor to the British minister for health on medical-social demographic issues, suggested as early as 1958 that the government erect underground sperm banks to protect the fertility of the United Kingdom in the case of a nuclear attack (Blacker 1958, 51). After successfully establishing a global sperm bank for animal husbandry, as well as regional blood banks for humans, the next step was to create similar institutions for human reproductive cells. Researchers were utterly convinced that this project was not merely ethically acceptable, but explicitly desirable.

Indeed, within the context of continuing biopolitical discussions on the issue of fertility control, Herbert Brewer, a longstanding correspondent of the Eugenics Society, saw in the cryopreservation of male gametes an appropriate dispositif through which to protect not only the reproductive strength of the population against nuclear threat, but also to secure against the technological dangers of modern life. He identified a relevant series of mutagenic factors: 'the increasing use of nuclear power in industry, . . . industrial and automobile fumes, foods and food additives, tobacco, drugs, antibiotics, hormones, cosmetics, contraceptives and agents of chemical warfare' (Brewer 1963, 56). The cryogenic storage of human reproductive cells promised sovereignty over reproductive behavior: in combination with appropriate birth control methods, unwanted pregnancies could be prevented. As the thinking went, with only healthy planned pregnancies coming to term, this project would inevitably lead to the creation of an ideal society.

Now that liquid nitrogen and the antifreeze agent glycerol were reliably available, new objects of investigation related to the circulation and storage of cryobiological products opened up: first, animal sperm and human blood, then human germ cells, and eventually entire organs and creatures. Audrey Smith (1961), a cryobiological pioneer and colleague of Parkes, had already begun to experiment with the freezing of small mammals in the 1950s. At first, the experiments failed completely, because the sheer mass of an animal carcass would not allow the glycerol to effectively coat every cell, and thus prevent the formation of ice crystals in the internal organs and brain. Flash freezing showed more promise, but it required an equally accelerated defrosting process. Here, James Lovelock, a colleague of Smith's (and the eventual originator of the Gaia theory) struck on a brilliant idea. He constructed the first device capable of quickly defrosting lab animals: the microwave oven (Andjus and Lovelock 1955; Lovelock and Smith 1956). What decades later would find a pride of place in millions of households to defrost frozen food was actually first used on a wholly different category of organic tissue: flash-frozen lab animals. With this device, eight out of twenty frozen hamsters survived the brief suspension of their vital functions at -5 °C.

These steps brought us even closer to achieving the ultimate utopia wherein humans could be cryogenically preserved long-term. In 1965, Robert C. W. Ettinger published his influential tome, *The Prospect of Immortality*, which evocatively leaned on the research of cryobiologists such as Smith and eventually became the 'bible' of the cryonics movement (Parry 2004). This movement rested its hopes of a cryogenic suspension of death on 'The Scientific Probability of the Revival and Rejuvenation of Our Frozen Bodies', or the subtitle of Ettinger's cryopolitical manifesto. Moreover, in the text's conclusion, Ettinger introduced his idea of a technosocial 'freezer-centered society', in which every individual had the right to access life-extending freezing technology (Ettinger 1965).

Whereas the realization of this cryobiological social utopia was still beset by countless obstacles, cryogenic culture was more successfully infiltrating reproductive medicine. Here, the core issue became the possibilities offered by the low-temperature storage of organic substances: 'Cryopreservation of semen and spare embryos has become a mainstay of the assisted reproduction technology (ART) laboratory' (Gosden 2011, 264). In 1954, the first human was born after artificial insemination with cryopreserved sperm (Bunge et al. 1954), and shortly thereafter, research shifted its sights toward the deep-freezing of egg cells. Upon the successful cryopreservation of mice ovum in the 1970s (Gook 2011, 282), the first cryobanks opened in the United States in order to make sperm donations more accessible. Following the arrival of healthy babies born of cryopreserved embryos and ovum (Trounson and Mohr 1983; Chen 1986), the world's first egg bank opened its doors in Melbourne in 1994.

These revolutionary successes in cryogenic reproductive technology were all due to improvements in the vitrification process, a method whereby flash freezing and the targeted use of antifreeze agents suppressed the crystallization of freezing water within the cell. At the beginning of the new century, the successes truly began to mount. The long-term storage of both male and female human reproductive cells became possible on a large scale. By 2010, more than half of the clinics specializing in reproductive medicine in the United States offered not only the cryopreservation of eggs but also artificial insemination services (Rudick et al. 2010). After more than a half-million babies were born from frozen embryos (Gosden 2011, 266) and the health ministries of numerous nations approved the use of such technology, officials on the Practice Committees of the American Society for Reproductive Medicine and the Society for Assisted Reproductive Technology (2013) decided to lift the designation of 'experimental' from the practice. The freezing of human germ cells for later use became a widely available commercial service (Quaas et al. 2013). Nonetheless, its economic and ethical status has remained contentious, both for laypeople and professionals in the field: To what extent are these tissue donations versus commercial products? Under what circumstances is their use legally and morally legitimate? (Ethics Committee of the American Society for Reproductive Medicine 2007; Lockwood 2011; Pennings 2013).

As these debates rage and the frozen storage of animal, human, and vegetable materials continues unabated, a veritable cryobiological archive has formed, which conspicuously points to its own biopolitical economy. Various actors came together to form dedicated working groups and special interest organizations, all with the goal of advancing the technology's economic potential and aligning it with state interests. In 2005, the cryobanks at major German research institutes came together to found the Gemeinschaft Deutscher Kryobanken e.V. Their mission statement states: 'Cryo-banks preserve the fundamental national bio-resources for the future', and their website goes on to explain that 'bio-samples' – the medical, agricultural, food-industrial, and ecological samples – stored therein:

> of different origin and composition are a unique and irreplaceable treasure for future research . . . [and must be used] . . . for reference or to improve our life standards and those of following generations. . . . It is therefore of supreme importance to continue the research on cryopreservation in the interests of humanity, by intensifying the support from the public sector.[6]

By invoking the idea of the 'common good', the coalition strategically used biopolitical arguments to solicit state funds for the further development of a refrigeration technology network, all 'for the national protection of bioresources' (ibid.). Should a catastrophe occur, only a stable network of cryobanks would be able to provide a seamless and secure supply chain of necessary materials. This credo of security no longer refers to just presently circulating perishables (both living and dead), but rather, to their future potential – and their immeasurable value for the health and prosperity of the general population. With that, state institutions are thus now expected – by dint of their responsibility for both the food supply and human tissue – to protect and ensure the security of the cold chain.

[6] http://www.kryobanken.de/ziele.php. Translated from the German. See also the articles of incorporation (28 October 2010).

Conclusion: Biopower in the age of cryogenic life, a look back and forward

Examining the historical development of both strands of refrigeration technology, it is clear that each strand did pursue its own goal. The horizontal line intended to keep deceased organisms fresh, so that they could nourish the living; the vertical line tried keep living organisms fresh, as a means of eluding death. Over the course of the twentieth century, these two lines converged in an attempt to fix a cryogenic hold over life itself. In order to achieve this goal, life was to be commuted into a cold-induced state, suspended in a place that both perpetually approached death while also moving away from it. As these two lines merged, the 'frosty life' that Luyet dubbed 'latent' became an ensemble of entities that circulated along a horizontal cold chain that was originally designed for perishables (for example, dead organisms) meant to be digested by the living. The vertical line, a deep-frozen ensemble of latent life, encompassed cryogenic stores of microorganisms, seeds, blood, sperm, organs, and much more. Such items could be put on ice anywhere in the world in order to then be reanimated somewhere else at an indeterminate point in time before finally being delivered to an appropriate organism that would extend, improve, or transform its life, for example, sperm to egg, meat to human, frozen pizza to suburban parent. Thus we can call the entirety of life made possible by cold-technological interventions 'cryogenic life'. Insofar as the ultimate goal of cryogenic life is to maintain life at its freshest – meaning, its best, most usable, most valuable form – it stands as a counter model to what Agamben (1998) described as 'bare life'. Cryogenic life is distinguishable from bare life, in that the former also encompasses the state of Luyet's 'latent life', which has been made possible through cold technology. By attempting to halt the entropic fate of organic beings, chilling technologies place these entities – and their future potentials – at the disposal of others.

The power that rules this disposition is biopower. In this discussion, this term cannot be taken literally enough (Gehring 2006, 12). Biocentric refrigeration technology enables the comprehensive regulation of biological and social life, in terms of 1) the production and preservation of perishables, 2) the medical treatment of organic substances and tissue, as well as 3) the climate control of human bodies and living spaces. Thanks to this dispositif of infrastructural refrigeration technology, biopower has attained a previously unimaginable control over life.

In light of these developments, Foucault's terminology must be reconsidered. Foucault himself developed the term to describe the emergence of the modern state and its processes of rule and subjectification – especially in terms of sexuality and racial dynamics (Foucault

1977, 2006b). In so doing, he laid bare the various techniques of rule that no longer focused, in a disciplinary fashion, on individual bodies, but that rather envisioned the regulation of an entire category of creation, so-called populations. Insofar as the dispositifs of biopower were focused on optimizing health, life expectancy, reproduction, hygiene, etc., the end goal was to bolster the strength, abilities, and productive potential of entire populations.

Our investigation into the development of modern cryogenic culture necessitates a revision of this term. It must now address a more comprehensive process: one that is part of the older definition, but also supersedes it by addressing not only populations, but life as a whole – the *bios* itself, as it were. This technology – as revolutionary as it is ordinary – for the continual optimization and organization of cryogenic life no longer addresses the relationship between the modern state and its citizens as biological creatures alone, but the relationship between modern society and all living things.

In a narrower, biological sense, this power is recognizable in the wide range of its applications in the food industry, biotechnology, and reproductive medicine. Yet, even as it infiltrates more areas of our lives, this pervasiveness retreats from human consciousness. Due to the exigencies of thermodynamics, cryogenic life must exile itself from its environment, while its use nonetheless remains ubiquitous in industrialized society. And that which is omnipresent is only noticeable when it no longer works. As the technologically perfected *conditio sine qua non* of industrialized living beings, refrigeration technology has until now seldom been the subject of serious reflection.

This article is an initial, exploratory attempt at making visible the constitutive functions of refrigeration for modern societies and at sketching its meaning for the formation of the 'bios' as 'cryogenic life'. Many questions still remain. As such, this research field offers promising new lines of investigation that can all help analyze the development of the cryopolitical landscape: for example, the development of medical 'hypothermia', the propagation of refrigerated vaccines, the organ trade, gene technology, and 'social freezing'. Some studies, however, already exist that productively point to new avenues of investigation, such as analyses of the commodification of human tissue in the expansion of biocapitalist economies (Cooper 2008; Parry 2006, 2008; Lettow 2012) and inspiring studies on gene-technological biopower (Bühl 2009).

It is crucial to build upon this foundation and to locate existing research within the context of historical and contemporary dynamics of cryogenic culture. The multifaceted manifestations and areas of influence of these developments also raise important questions about the mechanisms and institutions of cryogenic biopower. This biopolitical dispositive, formed by sociotechnical networks of heterogenous actors that operate through diffusive power dynamics, desperately requires new forms of regulation. As cryogenic culture enables new forms of control over life and death, the question of their biopolitical engineering and control becomes crucially relevant. At stake in the answer to this question is the very fate of that which we call 'life'.

References

Agamben, Giorgio. 1998. *Homo Sacer: Sovereign Power and Bare Life.* Stanford, CA: Stanford University Press.

Alleyne, Richard. 2010. 'Robert Boyle's Wish List'. *Telegraph*, 5 March. Accessed on 30 November 2016. http://www.telegraph.co.uk/news/uknews/7798201/Robert-Boyles-Wish-list.html.

Anderson, Oscar E. 1953. *Refrigeration in America; A History of a New Technology and Its Impact.* Princeton, NJ: Published for the University of Cincinnati by Princeton University Press.

Andjus, R. K., and J. E. Lovelock. 1955. 'Reanimation of Rats from Body Temperatures between 0 and 1 °C by Microwave Diathermy'. *Journal of Physiology* 128, no. 3: 541–46. https://doi.org/10.1113/jphysiol.1955.sp005323.

Association Internationale du Froid, eds. 1908. *Premier Congrès International Du Froid (Progress in refrigeration science and technology).* Paris: Secrétariat Général de l'Association Internationale du Froid.

Bacon, Francis. 1669. *Sylva Sylvarum; or, A natural History, in ten Centuries. Whereunto is newly added the History natural and experimental of Life and Death, or of the Prolongation of Life.* Edited by William Rawley. London: William Lee. https://doi.org/10.1037/13885-000.

Blacker, Carlos P. 1958. 'Artificial Insemination: the Society's Position'. *Eugenics Review* 50: 51–54.

Boyer, Paul S. 1992. *Urban Masses and Moral Order in America, 1820–1920*. Cambridge, MA: Harvard University Press.

Boyle, Robert. 1665. *New Experiments and Observations touching Cold, or, An experimental History of Cold begun to which are added an Examen of Antiperistasis and an Examen of Mr. Hobs's Doctrine about Cold by the Honorable Robert Boyle; Whereunto is annexed an Account of Freezing, brought in to the Royal Society by the learned Dr. C. Merret*. London: John Crook.

Brantz, Dorothee. Forthcoming. *Slaughterhouse City: Paris, Berlin and Chicago, 1780–1914*. Baltimore, MD: Johns Hopkins University Press.

Brewer, Herbert. 1963. 'Constructive Fertility Control through Sterilization'. *Eugenics Review* 55: 55–56.

Bühl, Achim. 2009. *Auf dem Weg zur biomächtigen Gesellschaft? Chancen und Risiken der Gentechnik*. Wiesbaden: VS Verlag für Sozialwissenschaften. https://doi.org/10.1007/978-3-531-91418-3.

Bunge, R. G., W. C. Keettel, and J. K. Sherman. 1954. 'Clinical Use of Frozen Semen: Report of Four Cases'. *Fertility and Sterility* 5, no. 6: 520–29. https://doi.org/10.1016/s0015-0282(16)31802-7.

Castells, Manuel. 2001. 'Der Raum der Ströme'. In *Der Aufstieg der Netzwerkgesellschaft*, edited by Manuel Castells, 431–84. Opladen: VS-Verlag. https://doi.org/10.1007/978-3-322-97534-8_7.

Chen, Christopher. 1986. 'Pregnancy after Human Oocyte Cryopreservation'. *Lancet* 327, no. 8486: 884–86. https://doi.org/10.1016/s0140-6736(86)90989-x.

Christopoulou, Christiana. 2013. 'Early Modern History of Cold: Robert Boyle and the Emergence of a New Experimental Field in Seventeenth Century Experimental Philosophy'. In *History of Artificial Cold, Scientific, Technological and Cultural Issues*, edited by Kostas Gavroglu, 21–51. Dordrecht: Springer. https://doi.org/10.1007/978-94-007-7199-4_2.

Clarke, Gary Norman. 2006. 'A.R.T. and History, 1678–1978'. *Human Reproduction* 21, no. 7: 1645–50. https://doi.org/10.1093/humrep/del067.

Clemen, Rudolf Alexander. 1923. *The American Livestock and Meat Industry*. New York: Ronald Press Co.

Cooper, Melinda. 2008. *Life as Surplus: Biotechnology and Capitalism in the Neoliberal Era*. Seattle: University of Washington Press.

Cronon, William. 1992. *Nature's Metropolis: Chicago and the Great West.* New York: Norton.

Cummings, Richard Osborn. 1949. *The American Ice Harvests: A Historical Study in Technology, 1800–1918*. Berkeley: University of California Press.

The Daily Dispatch. 1862. 'Send Ice!' *The Daily Dispatch,* 8 July, 1–2.

D'Eramo, Marco. 2003. *The Pig and the Skyscraper: Chicago – A History of Our Future*. London: Verso.

Delft, Dirk. 2014. 'The Cryogenic Laboratory of Heike Kamerlingh Onnes: An Early Case of Big Science'. In *History of Artificial Cold, Scientific, Technological and Cultural Issues*, edited by Kostas Gavroglu, 65–81. Dordrecht: Springer. https://doi.org/10.1007/978-94-007-7199-4_4.

Dienel, Hans-Liudger. 1991a. 'Eis mit Stil: Die Eigenarten deutscher und amerikanischer Kältetechnik'. In *Unter Null. Kunsteis, Kälte und Kultur*, edited by Centrum

Industriekultur Nürnberg und Münchner Stadtmuseum, 100–11. Munich: C.H. Beck.

Dienel, Hans-Liudger. 1991b. 'Ganz unten. Vom absoluten Nullpunkt und dem Nutzen tiefer Temperaturen'. In *Unter Null. Kunsteis, Kälte und Kultur*, edited by Centrum Industriekultur Nürnberg und Münchner Stadtmuseum, 86–99. Munich: C.H. Beck.

Emond, Jean-Pierre. 2008. 'Cold Chain'. In *RFID Technology and Applications*, edited by John R. Williams, Stephen B. Miles, and Sanjay E. Sarma, 144–56. Cambridge: Cambridge University Press. https://doi.org/10.1017/cbo9780511541155.012.

The Ethics Committee of the American Society for Reproductive Medicine. 2007. 'Financial Compensation of Oocyte Donors'. *Fertility and Sterility* 88, no. 2: 305–309. https://doi.org/10.1016/j.fertnstert.2007.01.104.

Ettinger, Robert C. W. 1965. *The Prospect of Immortality*. London: Sidgwick and Jackson Ltd.

Foucault, Michel. 1977. *Der Wille zum Wissen: Sexualität und Wahrheit Band 1*. Frankfurt am Main: Suhrkamp.

Foucault, Michel. 1980. 'The Confession of the Flesh'. In *Power/Knowledge: Selected Interviews and Other Writings,* edited by Colin Gordon, 194–228. New York: Pantheon.

Foucault, Michel. 1999. *In Verteidigung der Gesellschaft: Vorlesungen am Collège de France (1975–76)*. Frankfurt am Main: Suhrkamp.

Foucault, Michel. 2006a. *Sicherheit, Territorium, Bevölkerung: Geschichte der Gouvernementalität I*. Frankfurt am Main: Suhrkamp.

Foucault, Michel. 2006b. *Die Geburt der Biopolitik: Geschichte der Gouvernementalität II*. Frankfurt am Main: Suhrkamp.

Freidberg, Susanne. 2010. *Fresh: A Perishable History*. Cambridge, MA: Harvard University Press.

Gavroglu, Kostas. 2014a. 'Historiographical Issues in the History of Cold'. In *History of Artificial Cold, Scientific, Technological and Cultural Issues*, edited by Kostas Gavroglu, 1–17. Dordrecht: Springer. https://doi.org/10.1007/978-94-007-7199-4_1.

Gavroglu, Kostas, ed. 2014b. *History of Artificial Cold, Scientific, Technological and Cultural Issues*. Dordrecht: Springer. https://doi.org/10.1007/978-94-007-7199-4.

Gehring, Petra. 2006. *Was ist Biomacht? Vom zweifelhaften Mehrwert des Lebens*. Frankfurt am Main: Campus.

Giedion, Sigfried. 1982. *Die Herrschaft der Mechanisierung: ein Beitrag zur anonymen Geschichte*. Frankfurt am Main: Europäische Verlagsanstalt.

Gook, Debra A. 2011. 'History of Oocyte cryopreservation'. *Reproductive BioMedicine Online* 23, no. 3: 281–89. https://doi.org/10.1016/j.rbmo.2010.10.018.

Gosden, Roger. 2011. 'Cryopreservation: A Cold Look at Technology for Fertility Preservation'. *Fertility and Sterility* 96, no. 2: 264–68. https://doi.org/10.1016/j.fertnstert.2011.06.029.

Graham, Stephen, ed. 2010. *Disrupted Cities: When Infrastructure Fails*. New York: Routledge. https://doi.org/10.4324/9780203894484.

Griffiths, Ezer. 1924. 'The Fourth International Congress of Refrigeration'. *Nature* 114, no. 2859: 257–58. https://doi.org/10.1038/114257a0.

Hård, Mikael. 1994. *Machines Are Frozen Spirit: The Scientification of Refrigeration and Brewing in the 19th Century. A Weberian Interpretation.* Frankfurt am Main: Campus.

Hellmann, Ullrich. 1991. 'Höchst unauffällig. Der Aufstieg des Kühlschranks zur Unabdingbarkeit'. In *Unter Null. Kunsteis, Kälte und Kultur*, edited by Centrum Industriekultur Nürnberg und Münchner Stadtmuseum, 142–55. Munich: C.H. Beck.

'International Congress of Refrigeration'. 1923. *JAMA: The Journal of the American Medical Association* 80, no. 23: 1704. https://doi.org/10.1001/jama.1923.02640500046021.

Joyce, Patrick. 2003. *The Rule of Freedom: Liberalism and the Modern City*. London: Verso.

Justesen, Don R., and A. W. Guy. 1985. 'Arsène Jacques D'arsonval: A Brief History'. *Bioelectromagnetics* 6, no. 2: 111–14. https://doi.org/10.1002/bem.2250060203.

Kavaler, Lucy. 1972. *Freezing Point: Cold as a Matter of Life and Death*. Newton Abbot: David and Charles.

Kendrick, Douglas B. 1964. *Blood Program in World War II*. Edited by John Boyd Coates. Medical Department, United States Army in World War II. Washington: Office of the Surgeon General.

Korneffel, Peter. 2008. 'Handel mit gefrorenem Wasser: Der Eiskönig von Boston'. *Spiegel Online*, 8 December. http://www.spiegel.de/wirtschaft/handel-mit-gefrorenem-wasser-der-eiskoenig-von-boston-a-546120.html.

Leibo, Stanley P. 2004. 'The Early History of Gamete Cryobiology'. In *Life in the Frozen State*, edited by Barry J. Fuller, Erica E. Benson, and Nick Lane, 347–70. Boca Raton, FL: CRC Press. https://doi.org/10.1201/9780203647073.ch11.

Leibo, Stanley P. 2013. 'Milestones in Cryobiology'. *Cryobiology* 67, no. 3: 398. https://doi.org/10.1016/j.cryobiol.2013.09.007.

Lettow, Susanne. 2012. *Bioökonomie: Die Lebenswissenschaften und die Bewirtschaftung der Körper*. Bielefeld: Transcript. https://doi.org/10.14361/transcript.9783839416402.

Lockwood, Gillian M. 2011. 'Social Egg Freezing: the Prospect of Reproductive "Immortality" or a Dangerous Delusion?' *Reproductive BioMedicine Online* 23, no. 3: 334–40. https://doi.org/10.1016/j.rbmo.2011.05.010.

Lovelock, J. E., and Audrey U. Smith. 1956. 'Studies on Golden Hamsters during Cooling to and Rewarming from Body Temperatures below 0 °C. III. Biophysical Aspects and General Discussion'. *Proceedings of the Royal Society of London. Series B, Biological Sciences* 145, no. 920: 427–42. https://doi.org/10.1098/rspb.1956.0054.

Luyet, Basile J., and Marie Pierre Gehenio. 1940. *Life and Death at Low Temperatures*. Normandy, MO: Biodynamica. https://doi.org/10.5962/bhl.title.6570.

Mantegazza, Paolo. 1866. 'Sullo sperma umano'. *Rendiconti Istituto Lombardo di Science e Lettere* 3: 183–96.

Mendelssohn, Kurt. 1966. *Die Suche nach dem absoluten Nullpunkt*. Munich: Kindler.

Mumford, Lewis. 1970. *The Myth of the Machine*. New York: Harcourt Brace Jovanovich.

Murko, Matthias. 1991. 'Kälte gegen Krankheit und Tod. Auf dem eisigen Pfad des Überlebens'. In *Unter Null: Kunsteis, Kälte und Kultur*, edited by Centrum Industriekultur Nürnberg und Münchner Stadtmuseum, 17–36. Munich: C.H. Beck.

Nagengast, Bernard. 1999. 'A History of Comfort Cooling Using Ice'. *ASHRAE Journal*, February: 49–57.

Nagengast, Bernard, and Wolf Eberhard Kraus. 2005. *Air Conditioning and Refrigeration Chronology*. American Society of Heating, Refrigerating and Air-Conditioning Engineers. https://www.ashrae.org/File%20Library/docLib/Public/200651081623_347.pdf.

Ogle, Maureen. 2013. *In Meat We Trust: An Unexpected History of Carnivore America*. Boston: Houghton Mifflin Harcourt.

Papanelopoulou, Faidra. 2009. 'The International Association of Refrigeration through the Correspondence of Heike Kamerlingh Onnes and Charles-Édouard Guillaume, 1908–1914'. *Annals of Science* 66, no. 3: 345–70. https://doi.org/10.1080/00033790902976189.

Parkes, A. S. 1956. 'Preservation of Living Cells and Tissues at Low Temperatures'. In *Proceedings of the III International Congress on Animal Reproduction,* Cambridge.

Parkes, A. S. 1964. 'Cryobiology'. *Cryobiology* 1, no. 1: 3. https://doi.org/10.1016/0011-2240(64)90014-8.

Parry, Bronwyn. 2004. 'Technologies of Immortality: The Brain on Ice'. *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences* 35, no. 2: 391–413. https://doi.org/10.1016/j.shpsc.2004.03.012.

Parry, Bronwyn. 2006. 'New Spaces of Biological Commodification: The Dynamics of Trade in Genetic Resources and Bioinformation'. *Interdisciplinary Science Reviews* 31, no. 1: 19–31. https://doi.org/10.1179/030801806x84228.

Parry, Bronwyn. 2008. 'Entangled Exchange: Reconceptualising the Characterisation and Practice of Bodily Commodification'. *Geoforum* 39, no. 3: 1133–44. https://doi.org/10.1016/j.geoforum.2007.02.001.

Pennings, Guido. 2013. 'Ethical Aspects of Social Freezing'. *Gynécologie Obstétrique & Fertilité* 41, no. 9: 521–23. https://doi.org/10.1016/j.gyobfe.2013.07.004.

Polge, C. 2006. 'Sir Alan Sterling Parkes. 10 September 1900–17 July 1990: Elected FRS 1933'. *Biographical Memoirs of Fellows of the Royal Society* 52: 263–83. https://doi.org/10.1098/rsbm.2006.0019.

Polge, C., A. U. Smith, and A. S. Parkes. 1949. 'Revival of Spermatozoa after Vitrification and Dehydration at Low Temperatures'. *Nature* 164, no. 4172: 666. https://doi.org/10.1038/164666a0.

The Practice Committees of the American Society for Reproductive Medicine and the Society for Assisted Reproductive Technology. 2013. 'Mature Oocyte Cryopreservation: A Guideline'. *Fertility and Sterility* 99, no. 1: 37–43. https://doi.org/10.1016/j.fertnstert.2012.09.028.

Quaas, Alexander M., Alexander Melamed, Karine Chung, Kristin A. Bendikson, and Richard J. Paulson. 2013. 'Egg Banking in the United States: Current Status of Commercially Available Cryopreserved Oocytes'. *Fertility and Sterility* 99, no. 3: 827–31. https://doi.org/10.1016/j.fertnstert.2012.10.047.

Radin, Joanna. 2013. 'Latent Life: Concepts and Practices of Human Tissue Preservation in the International Biological Program'. *Social Studies of Science* 43, no. 4: 484–508. https://doi.org/10.1177/0306312713476131.

Radkau, Joachim. 2008. *Technik in Deutschland: vom 18. Jahrhundert bis heute*. Frankfurt am Main: Campus.

Rees, Jonathan. 2013. *Refrigeration Nation: A History of Ice, Appliances, and Enterprise in America*. Studies in Industry and Society. Baltimore, MD: Johns Hopkins University Press.

Rees, Jonathan. 2014. 'The Invention of Refrigerated Transport and the Development of the International Dressed Meat Trade'. In *History of Artificial Cold, Scientific, Technological and Cultural Issues*, edited by Kostas Gavroglu, 251–65. Dordrecht: Springer. https://doi.org/10.1007/978-94-007-7199-4_13.

Root, Waverley Lewis, and Richard Rochemont. 1976. *Eating in America: A History*. New York: Morrow.

Rudick, Briana, Neisha Opper, Richard Paulson, Kristin Bendikson, and Karine Chung. 2010. 'The Status of Oocyte Cryopreservation in the United States'. *Fertility and Sterility* 94, no. 7: 2642–46. https://doi.org/10.1016/j.fertnstert.2010.04.079.

Schmidt, Paul J. 2006. 'Basile J. Luyet and the Beginnings of Transfusion Cryobiology'. *Transfusion Medicine Reviews* 20, no. 3: 242–46. https://doi.org/10.1016/j.tmrv.2006.03.004.

Shachtman, Tom. 1999. *Absolute Zero and the Conquest of Cold*. Boston: Houghton Mifflin.

Sinclair, Upton. 1906. *The Jungle*. New York: Doubleday, Jabber & Company.

Sloane, T. O'Conor. 1900. *Liquid Air, and the Liquefaction of Gases; Theory, History, Biography, Practical Applications, Manufacture*. New York: Henley.
Smith, Audrey U. 1961. *Biological Effects of Freezing and Supercooling*. Baltimore, MD: Williams & Wilkins.
Smith, Audrey U., ed. 1970. *Current Trends in Cryobiology*. New York: Plenum Press. https://doi.org/10.1007/978-1-4757-9933-0.
Starr, Douglas P. 2000. *Blood: An Epic History of Medicine and Commerce*. New York: Quill.
Täubrich, Hans-Christian. 1991. 'Eisbericht. Vom Handel mit dem natürlichen Eis'. In *Unter Null. Kunsteis, Kälte und Kultur*, edited by Centrum Industriekultur Nürnberg und Münchner Stadtmuseum, 50–67. Munich: C.H. Beck.

Thoms, Ulrike. 2014. 'The Introduction of Frozen Foods in West Germany and Its Integration into the Daily Diet'. In *History of Artificial Cold, Scientific, Technological and Cultural Issues*, edited by Kostas Gavroglu, 201–29. Dordrecht: Springer. https://doi.org/10.1007/978-94-007-7199-4_11.
Thomson, J. Richard. 1964. 'Current Applications of Biological Science'. *Bios* 35: 202–207.
Trounson, Alan, and Linda Mohr. 1983. 'Human Pregnancy Following Cryopreservation, Thawing and Transfer of an Eight-Cell Embryo'. *Nature* 305, no. 5936: 707–709. https://doi.org/10.1038/305707a0.
Tschoeke, Jutta. 1991a. 'Frostige Glieder: Aspekte der Kühlkette'. In *Unter Null. Kunsteis, Kälte und Kultur*, edited by Centrum Industriekultur Nürnberg und Münchner Stadtmuseum, 128–41. Munich: C.H. Beck.
Tschoeke, Jutta. 1991b. 'Kälteburgen für Eier und Kaviar: Zur Ikonographie des Kühlhauses'. In *Unter Null: Kunsteis, Kälte und Kultur*, edited by Centrum Industriekultur Nürnberg und Münchner Stadtmuseum, 112–27. Munich: C.H. Beck.
Turner, Arthur R. 1970. *Frozen Blood: A Review of the Literature 1949–1968*. New York: Gordon and Breach.
Twilley, Nicola. 2014. 'Is Your Refrigerator Running? Why Overreliance on Refrigeration Is Making Us Less Safe'. *Modern Farmer*, January. http://modernfarmer.com/2014/01/refrigerator-running/.
Watkins, Helen. 2002. 'Fridge Stories'. In *Transforming Spaces: The Topological Turn in Technology Studies*, edited by Mikael Hård, Andreas Lösch, and Dirk Verdicchio. Darmstadt. http://www.ifs.tu-darmstadt.de/fileadmin/gradkoll//Publikationen/transformingspaces.html.
Whittemore, E. C. 1994. '19th Century Ice Harvesting'. *Antiques Magazine* 29: 32–34.