CHAPTER 6

# Fossilizing Snowflakes, or How to Freeze a Frozen Object

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## Fleeting but Permanent

In a storeroom in Cambridge lies a cardboard box that once contained a selection of fine Jamaican cigars. The label, *La Tropical De Luxe*, was one of the Machado Tobacco Company's best known, having been registered as Jamaica's second ever trademark.[1] Today, this particular box contains a vintage of a different kind: seventy-year-old snow crystals, frozen in plastic, and stuck to microscope slides wrapped in thin packing paper. The crystals were captured by British geographer and glaciologist Harold "Hal" Lister (1921–2010) at South Ice, a research base in West Antarctica that saw service during the Commonwealth Trans-Atlantic Expedition (TAE, 1955–58). Together with two other researchers, Lister spent the winter of 1957 at South Ice conducting research on snow and ice, which included creating plastic molds of snow crystals for microscopic examination.

These snowflake molds embody a tension between ephemerality and permanence: a fleeting object rendered permanent in plastic. This tension is central to the study of snow and ice in the Antarctic, not to mention the cryosphere writ large. Consider, for instance, the popularity of the "archive" metaphor to describe polar ice and the cores extracted from it. Pioneering ice-core researchers described these objects as "frozen annals," extracted from the icy "treasure troves" where events of the past were "separately and safely filed for future reference."[2] These archives are hundreds of thousands of years old, and count among the most important and continuous records of climatic change. Yet that same climatic change is rendering them ever more impermanent.[3] The making of snowflake molds constitutes a different kind of icy archive, one that





**Figure 6.1.** *La Tropical de Luxe* cigar box, now containing six stacks of microscope slides wrapped in packing paper. © Floris Winckel. Y2022/9/1, Scott Polar Research Institute, University of Cambridge, with permission.

involves different practices, temporalities, and affective connections. Although modest in size, the history and materiality of these artifacts can help us understand fundamental aspects of the study of snow and ice in the Antarctic.

Responding to a recent call to focus on what "elemental substances such as ice" can tell us about knowledge making and contemporary environmental concerns, this chapter is in part a call to diversify our understanding of what it means to study the cryosphere and its material culture.[4] It begins with a brief overview of attempts to preserve snow crystals in plastic, a method that offered a convenient way for researchers to observe these objects, particularly in challenging environments. I then examine the Lister slides more closely, focusing in particular on how they were used, how they represented a promise to overcome the challenges of studying snow, and ultimately how they fell short of this promise. I argue that these artifacts help bring into relief practices of making permanent, which are especially crucial in a region such as the Antarctic and which extend beyond the science of snow and ice.

## Fixing Flakes

Snowflakes are notoriously ephemeral things. It can take up to an hour for them to fall to the ground, but once they land, they immediately begin

to melt and transform. Any increase in the ambient air temperature accelerates this process of transformation. For much of the history of studying these objects, this increase in ambient temperature was often caused by the proximity of the observer's body; the irony of studying a snow crystal's intricate and beautiful form being that the closer one looked, the faster it disappeared. Observers developed a number of strategies to mitigate this deterioration, from cooling down equipment to capturing the object's image faster. One strategy that gained prominence in the mid-twentieth century involved fixing snow crystals by applying adhesives, such as natural or synthetic resins.

Early attempts produced mixed results. The first, by Japanese physicist Ukichirō Nakaya in the mid-1930s, involved using a solution of rosin—the resin from conifers that violinists use to rub their bowstrings with—dissolved in chloroform. As the chloroform evaporated, the rosin hardened around the crystals.[5] The degree of permanence Nakaya achieved with this method was limited: the rosin molds would last for only a few days, and the crystals seemed to become partially dissolved during the hardening process. In the winter of 1941 to 1942, somewhere above the German Alps, meteorologist Helmut Weickmann was able to capture snow crystals in clouds by holding Plexiglas plates coated in Zapon lacquer—a nitrocellulose lacquer similar to nail polish—out of an airplane. Although spectacular, this method was difficult to get consistent results with: crystals often shattered on impact, and it was a matter of luck whether the lacquer layer had the right consistency for crystals to leave impressions in it.[6]

What Weickmann did not know was that an "extremely simple" method of fixing snow crystals had already been developed earlier in 1941 by Vincent Schaefer, a researcher at the General Electric Research Laboratory in Schenectady, New York. The method, which he called the "replica technique," first involved making a weak (1 percent) solution of a polyvinyl formal (commercially known as Formvar), dissolved in ethylene dichloride, and cooled to below freezing. Once a suitable flake had been captured on a strip of velvet or other dark material, a thin utensil (such as a toothpick or wire) was dipped in the solution and used to place a drop of it on a microscope slide. The same utensil was used to pick up the flake and lift it onto the slide, such that it became completely submerged in the solution (a second drop could be added on top for good measure). As the solvent evaporated, the resin would harden around the flake in minutes.[7] At this point the slide could be left in a warm place to allow the ice to completely sublime.[8] Schaefer described this method as making "fossil" snowflakes.

The possibilities that the replica technique offered were immediately evident. Schaefer's 1942 article on the technique featured thirty-six photomicrographs of snow crystals, taken from a collection of 150 replica crystals that he fossilized over the course of a thirty-minute snowstorm the previous year. For context, a century earlier it had taken James and Cecilia Glaisher four weeks to draw the same number of snow crystals from their South London living room.[9] Even Wilson Bentley, who published a famous book containing some two thousand snowflake photographs only a decade before Schaefer's article came out, could at most take a few dozen photographs per day.[10] On top of this, the new method was simple and inexpensive, and allowed specimens to be "photographed and studied at leisure."[11]



Over the course of the next two decades, the replica technique became widely used and adapted. It was used to create cross sections of snowpack in the petrofabric analysis of snow, it enabled electron-microscope studies of snow crystals (otherwise impossible due to their fragility), and it could be deployed to study other microscopic objects such as bacteria. Johannes Grunow, a German meteorologist, considered the technique "indispensable" in upper air studies, enabling many "durable" but also detailed copies of crystals to be made, and allowing for "evaluation and photographic elaboration at any later time and at any place."[12] A significant factor in the replica technique's popularity was also its usefulness for researchers working in extreme environments: outside of a flying aircraft; on top of a mountain; and of course in the polar regions. Already by 1947, supplies of polyvinyl formal solution and microscope slides were on their way to Norway, the Himalayas, and the Weddell Sea.[13] In 1956, Marcel de Quervain, director of the Snow and Avalanche Research Institute in Davos, prescribed the use of the technique as part of the glaciological research program of the International Glaciological Greenland Expedition (1957–60).[14] A decade later, Katsuhiro Kikuchi from Hokkaido University made six hundred replicas of snow crystals in the Antarctic in just thirteen months.[15] Then there is Hal Lister, who was likely the first to use the technique on both Poles. It was never a prominent part of his glaciological research. Yet despite this, a close examination of how he made his replicas can help us think about the broader significance of materiality and permanence in the study of Antarctic snow and ice. With that in mind, let us return to our Jamaican cigar box.

## The Lister Replicas

The microscope slides in figure 6.2 form part of a larger collection of 240 slides recently donated to the Scott Polar Research Institute by Hal Lister's relatives. These include the South Ice replicas, as well as replicas

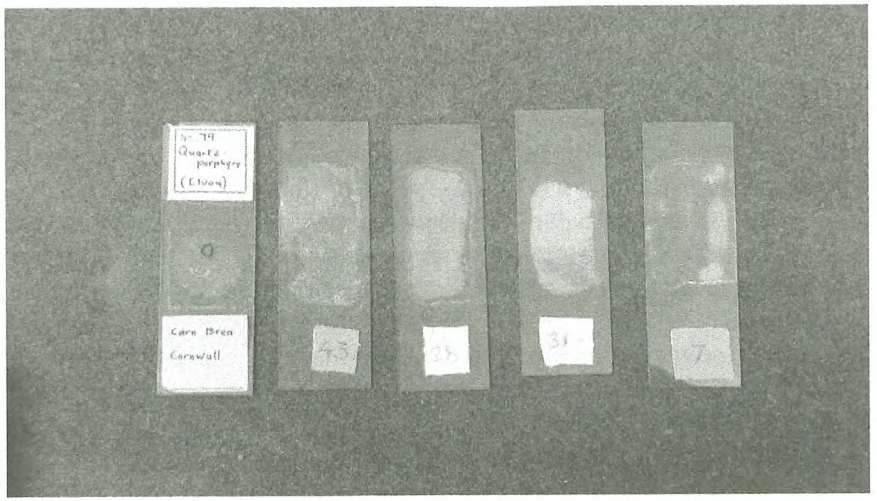



**Figure 6.2.** Replica slides of snow captured in the Antarctic, unboxed and unwrapped. On the far left is a slide containing a rock sample from Cornwall, likely to be used for comparing crystal structure (notice the small black circle to highlight a particular section of the sample). © Floris Winckel. Y2022/9/3, Scott Polar Research Institute, University of Cambridge, with permission.

he had made on the British North Greenland Expedition (BNGE) between 1952 and 1954. Lister had joined the BNGE as a glaciologist shortly after starting his doctoral studies at Cambridge University. He completed his dissertation on High Arctic glaciers in 1956, and in November of that year left for Antarctica to join the TAE, also as a glaciologist. In Antarctica he was responsible for designing and carrying out the TAE's glaciological program, which focused mainly on the heat and mass balance of the snow surface. Having already employed it in Greenland, Lister included the replica technique early on in his designs for the TAE glaciological program. Already in June 1956, soon after being appointed glaciologist to the TAE, he wrote to two chemical companies, Shawinigan Limited and Imperial Chemical Industries, to request supplies of polyvinyl formal and ethylene dichloride. This was even before he first presented his full glaciological program to expedition leader Vivian Fuchs.[16]

The replica technique that Lister was so keen on employing formed part of his investigation into snow accumulation, the three main forms of which are precipitation (snowfall), drift, and condensation. The TAE replicas are of drift snow, namely the crystals and fragments of crystals blown across the landscape. Lister described drift as the "dominant characteristic of polar regions."[17] It penetrated clothing, obscured vision, wiped away ski tracks, and behaved like an "almost continuous moving



carpet" across the ice.[18] It was a hindrance even when not on the move, burying supplies and buildings on a regular basis, and generally frustrating the expedition members. Even though snow crystals themselves may be ephemeral, drift snow as a whole "persisted most of the time."[19]

The replicas were used to measure the form and size of the drift particles, and to determine particle counts for different wind speeds. Lister mostly followed Schaefer's instructions for making them. Figure 6.3 shows how the solution was applied to microscope slides using the base of a thin paintbrush. This was done at the "snow-flake bench," a separate nook in the underground bunker that was South Ice station, where the slides could be prepared without worrying about interference from wind and snow.[20] In the background of the photograph we see a shelf lined with instruments and chemicals, including an opened can of what is likely the polyvinyl formal. Once coated, the slides were mounted in a streamlined box (figure 6.4) and exposed to blowing drift. This was done at different heights, from a few centimeters to ten meters above ground, until an even coating of particles covered the slide (the time taken to reach an even coating increased with height). Once the slide had been coated, it was taken inside to let the solvent evaporate and the crystals



**Figure 6.3.** Application of polyvinyl formal solution to a microscope slide. P2014/10/1, Folder 7 Slide 42, Scott Polar Research Institute, University of Cambridge, with permission from Newcastle University Special Collections and Archives.



**Figure 6.4.** Closeup of the streamlined box, as a labeled microscope slide mounted in a wooden bracket is placed in it. P2018/34, Folder 2 Slide 43, Scott Polar Research Institute, University of Cambridge, with permission.

sublime through the hardened resin. The particles could then be examined under a microscope and measured. Up to four thousand particles were measured in this way by Lister and his two colleagues at South Ice, Kenneth Blaiklock—likely the man in figure 6.3—and Jon Stephenson.[21] A few replicas were later photographed and published in the TAE glaciological report.

To illustrate some of the key difficulties of working with snow in the Antarctic, and to understand how the replica method promised to overcome them, consider Lister's use of photography to analyze the movement of drift particles across the landscape. Temperatures below -20°C were common at South Ice and often made instruments and equipment malfunction; Lister notes that even his portable equipment that had been rated for use at very low temperatures failed to work properly.[22] Both the camera and the film needed to be heated to prevent damage to the equipment. The whole apparatus was therefore placed in an insulated box, but this made using it tricky. Solenoids were used to remotely operate many of the camera mechanisms, but low temperatures still required some actions—like the rewinding of the film—to be done by hand to prevent tearing. Visibility was also an issue. Photographing the crystals near to the ground was difficult, because the white particles were barely



visible against the white snowpack. Like many observers before him, Lister noted the usefulness of a black cloth to provide a contrasting background; but this interfered with the drift as it moved—the core behavior he hoped to study. Illuminating the particles was also a challenge: during the Antarctic winter, perpetual darkness made artificial light a necessity, but powering the flash tube also added an additional burden to South Ice's already insufficient power supply (which was also being used to heat the camera and film).[23] Unfortunately, "the flash tube was broken during 'social' photography before the return of the sun," leading to a premature end to the photography experiments—the nature of Antarctic expeditions being such that replacements for irreparable instruments could not quickly be ordered and delivered.[24]

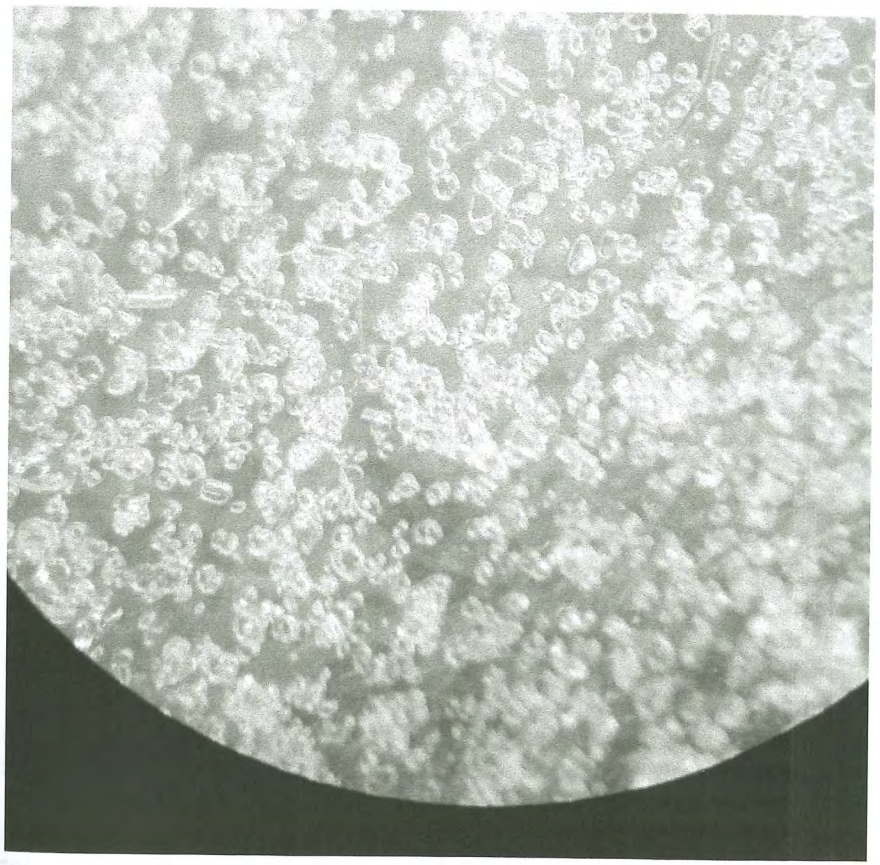


**Figure 6.5.** View through the microscope (magnification unknown) of one of the TAE slides. Individual particles are hard to distinguish, and recognizable snow crystals are rare. © Floris Winckel. Y2022/9/6, Scott Polar Research Institute, University of Cambridge, with permission.

The replica technique seemed to overcome many of these issues: few materials were required; they did not have any moving parts; the slides could be prepared in advance; time outside could be minimized; and all analysis could be carried out in a relatively comfortable indoor environment with no risk of material loss.[25] However, years later, Lister recalled that all his methods of studying drift snow "were less than hoped because of the wild and cold environment slowing all activities outdoors."[26] In fact, there were a number of factors that meant the replica technique did not live up to its promise of overcoming ephemerality in Antarctic snow research. A look at some of these factors reveals just how delicate the tension between ephemerality and permanence is.

Although often presented as a means to render snow crystals stable in contrast to their natural tendency to melt and disappear, the actual stability offered by the replica technique could not be taken for granted. We see this clearly on the lid of the cigar box, on which Lister wrote "Microscope Slides of Snow & Drift VERY FRAGILE Please!!" Glass microscope slides and thin plastic films are indeed fragile things, especially when being transported halfway across the world. In fact, several slides in the Scott Polar collection are cracked or broken in half, although it is difficult to tell at what point the damage was done. The warning also echoes a broader challenge for glaciological research in Antarctica, namely the difficulty of handling and transporting icy specimens. Jessica O'Reilly notes that "while the data read from the ice may be permanent, the material itself can be destroyed before scientists can read it."[27] O'Reilly refers here to the handling of ice cores, but her point still stands in the case of the Lister replicas: even after the form of the ice is transferred to plastic, a sense of fragility remains.

As with so many scientific experiments, the usefulness of the replica technique also relied on the skill and expertise of the experimenter. For instance, the Lister slides were coated in a much stronger 10 percent polyvinyl formal solution compared to Schaefer's recommended 1 percent. One explanation for this is that Lister noticed a reduction in a phenomenon called "flocculation." This happened when the slide was not held completely level, or experienced vibrations during exposure, leading to the solution flowing across its surface and causing the crystals to bunch up. Both factors certainly played a role in Lister's case, given that the slides were handheld in windy conditions during exposure. Increasing the concentration of the solution made it more viscous, reducing its tendency to flow across the slide, but conversely making it harder for smaller crystals to be fully submerged in the solution; these may look broken under the microscope, when in reality they were intact. Lister admits that the many shattered particles were "impossible" to define, save for those at the edges of the slides. This was not ideal, given his analysis relied on measuring the length and width of each particle, typically on the order of tenths of millimeters.[28] A notebook among his papers containing thousands of individual measurements and calculations, recorded in neat columns, hints at how painstaking this work must have been.[29] Other factors could also complicate the analysis of replica slides, such as temperature differences between the solution and the ambient air, or water vapor condensing on the slide while it hardened (especially water vapor originating from faces or hands—recall figure 6.3).[30] Lister took care to avoid some types of contamination, but all of these factors could introduce uncertainty into the reliability of what was captured in the plastic.



More can be inferred about the limits of the replica technique from comparing the TAE slides to the BNGE slides that Lister made a few years earlier. For objects that were made using the same technique by the same person, they differ in various ways. Most of the BNGE slides were individually wrapped and labeled with date, time of day, data on a variety of atmospheric conditions, and a short description of the crystals on the slide. Since the technique was used to collect both drift and falling snow in Greenland, many more large and intact crystals can be seen compared to the drift slides from Antarctica, which due to South Ice's windy, cold, and relatively dry conditions, feature mostly small, shattered crystals (see figure 6.5). The presence of intact crystals may also explain why some BNGE slides contain red circles, drawn in pen or wax, highlighting certain areas of the film and particular specimens for later analysis. Such differences seem to suggest a difference in research questions, but in general terms the BNGE and TAE glaciological programs were very similar: both included studies of the regime of the ice, or the degree of accumulation during the winter months and the degree of ablation during the summer months. What is odd is that published summaries and results from the BNGE glaciological program do not mention the replicas.[31] This despite the fact that the slides were made across multiple months and clearly involved careful recording and cataloging (many labels were typed, for instance). In one of the few passages in Lister's memoirs where he refers to the slides, he refers to them as "souvenirs," hinting at how they may have had more emotional and aesthetic value for him than scientific.[32] The only record of his replica activities in Greenland that I could find was given by Harold Lewis, a South-African physiologist on the expedition, who recalled that Lister "often showed us the delicate tracery of the snowflakes under the microscope, and explained the problems of distinguishing precipitated snow from drift."[33]

The contrast between "delicate tracery" and the difficulty of distinguishing snow types speaks to the two-sided nature the slides: they were enticing to look at under a microscope but limited in their scientific usefulness. Lister mentioned that his methods of studying drift were ultimately "less than hoped," but there were few better alternatives at the time. A team of Australian researchers who followed up on Lister's studies in the Antarctic a decade later maintained that it was still "the standard method for the study of particle shapes and sizes," despite simultaneously acknowledging that "[i]n practice it has proved difficult to apply under snow drift conditions."[34] Focusing on the materiality of the replica technique brings into relief some of the fundamental challenges in studying snow and ice, challenges accentuated in regions such as the Antarctic: dealing with low temperatures; limited access to specialized equipment; handling and transporting fragile or sensitive objects. Condensed in Lister's replicas is the promise of a cheap and convenient way to overcome ephemerality and make permanent in the study of snow and ice.

## "It'll Last Forever"

In Season 3, Episode 1 of *The Big Bang Theory* (2007–19), Leonard (Johnny Galecki) gifts Penny (Kaley Cuoco) a snowflake from the North Pole. "It'll last forever," he explains, "I preserved it in a 1 percent solution of polyvinyl acetyl resin." The single crystal is so small that Penny initially cannot see it. Her reaction when she finds out what it is ("Are you serious?!") speaks to the wonder of holding a snowflake at room temperature. Or is it the jarring experience of seeing a delicate snowflake frozen in plastic? Or the disbelief that something so small and fragile survived a journey from the Arctic to California? Her reaction distills the tension inherent in this once fleeting, now plastic flake. But it is Leonard's first three words that capture the polyvinyl resin's core value: to make that flake last forever.

To peer through a microscope and see seventy-year-old snow is unusual. Snow and ice sciences tend not to leave behind specimens in the same way that botanical or geological sciences do, with the notable exception of the many ice-core samples currently stashed away in polystyrene boxes and low-temperature storage rooms across the world. The nature of snow and ice is such that they are often only studied in the moment, and if they are materially preserved, it is usually through sophisticated cold storage and transportation infrastructure. But different types of snow and ice demand different kinds of interactions. The Lister slides remind us that there is also something highly trivial about making



snow and ice permanent: it does not have to require drilling and refrigerating—snow can be shipped across the world in a cigar box.

Snowflake fossils bring into relief the tension between ephemerality and permanence in the cryosphere, and the key role practices of making permanent play in the study of regions like the Antarctic. Such practices complement a growing interest in the nature of ice as both the object and means of artificial preservation, manifested for example in recent work on the technological, social, political, and ethical dimensions of extending the lifetimes of organic materials through freezing and refrigeration, from seed-banks to the global circulation of food.[35] Such attention to preservation is especially pertinent in an Antarctic context, and extends beyond organic materials and snowflakes to the continent itself.

By enshrining its status as a "natural reserve, devoted to peace and science," the signatories of the Protocol on Environmental Protection to the Antarctic Treaty (1991) hoped to ensure that "Antarctica shall continue forever."[36] This wording obscures the impermanent nature of the place: as Lister described, snow drift creates a constantly shifting landscape; and as he calculated, that landscape is constantly losing and gaining snow. It is also worth remembering that the impermanence of human livelihoods and activities there—marked, for instance, by the lack of permanent residents and the agreement to minimize the ecological footprint of scientific research—means that all knowledge, knowledge actors, tools of knowledge, knowledge infrastructures, and so forth must necessarily leave at some point. As a place where the idea and challenge of permanence is brought into relief, the Antarctic becomes a key site for revealing the nature and materiality of preservation practices writ large. The Lister replicas alone do not represent a major event in this context. But by analyzing these modest cases of an ephemeral nature made permanent, we can start to appreciate permanence-making as a core part of Antarctic science.

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## NOTES

1. Stubbs, "Political Idealism and Commodity Production," 60.
2. Dansgaard, *Frozen Annals*; Henri Bader, as cited in Rider, "'The Agent of the Most Dire of Calamities,'" 163.
3. Rider, "Ice," 90–91.
4. Dodds and Sörlin, "Ice Humanities," 10.
5. Nakaya, "Yuki No Kaseki 1," 48–49; Nakaya, "Yuki No Kaseki 2," 91–98.
6. Weickmann, *Die Eisphase in der Atmosphäre*, 22–23.
7. Hallett, "Replica Technique for the Study of Snow Crystals," 40.
8. Schaefer, "A Method for Making Snowflake Replicas," 239–40.
9. Glaisher, "On the Severe Weather at the Beginning of the Year," 16–30.
10. Bentley, "Studies among the Snow Crystals," 2; Bentley and Humphreys, *Snow Crystals*.
11. Schaefer, "Use of Snowflake Replicas," 81. "If this all sounds complicated," he quipped, after explaining the technique to readers of *Natural History* magazine, "perhaps I should say that one of my best pupils has been a seven-year-old girl." Schaefer, "How to Fingerprint a Snowstorm," 22.
12. Grunow and Huefner, *Observations and Analysis of Snow Crystals*, 5, 13–14, 18–20.
13. "'Snow and Clouds in the Sky' V.J. Schaefer, Manuscript, 1947 April 09," M. E. Grenander Department of Special Collections and Archives, Albany, NY, Vincent J. Schaefer Papers, Series 2, Subseries 3, Box 10, Folder 3, fol. 1; Press Release, "Finn Ronne Research Antarctic Expedition takes a supply of materials and instructions from Vincent Schaefer on the preservation of snow crystals," Museum of Innovation and Science, Schenectady, NY, Roger Hammond Collection, PC015, fol. 1.
14. de Quervain, "Internationale Glaziologische Groenlandexpedition (EGIG): Programmvorschläge zur Schneekunde," 1956, Interner Bericht Nr. 230, Snow and Avalanche Research Institute Archive, Davos, 4.
15. Kikuchi, "Unknown and Peculiar Shapes of Snow Crystals," 99–116.
16. The relevant letters and documents date from 19 June to 5 July and can be found in "Glaciology I and II," Scott Polar Research Institute, Cambridge, United Kingdom (SPRI), Papers of the Commonwealth Trans-Antarctic Expedition, MS 1326/13/3/1.
17. Lister, *Glaciology*, 3.
18. Lister, *Ice*, 59.
19. Lister, *Ice*, 89.
20. Lister, *Ice*, 94. The list of required apparatus in Lister's first draft of the TAE glaciological program included three hundred microscope slides. About a hundred of these made it to the collection in Cambridge. "Notes for Eleanor, 28 June 1956", SPRI, MS 1326/13/3/1, fol. 10.
21. Lister, *Glaciology*, 16.
22. Not just scientific instruments but also other mechanical equipment such as wristwatches could suffer from the cold. See McCahey, "Extreme Environments and the Production of Scientific Knowledge," 175.
23. In letters exchanged between Lister and expedition leader Vivian Fuchs, the former complained that the allotted power for South Ice would not suffice for his research. SPRI, MS 1326/13/3/1.
24. Lister, *Glaciology*, 18.
25. Relatively being the key word: indoor temperatures were often still below freezing at ceiling level. Lister, *Ice*, 96.
26. Lister, *Ice*, 98.
27. O'Reilly, *The Technocratic Antarctic*, 70–71.
28. Lister, *Glaciology*, 16.
29. "Glaciology B," SPRI, Harold "Hal" Lister Papers, MS 2234/3/7.
30. Griggs and Jayaratne, "The Replication of Ice Crystals Using Formvar," 547–51.
31. Lister, "British North Greenland Expedition," 110; Hamilton, "The British North Greenland Expedition, 1952–54," 1030–32, 1031; Hamilton et al., "British North Greenland Expedition 1952–4," 203–37, 235.
32. Lister, *Ice*, 98. Since its invention, the replica technique has enjoyed widespread appeal, particularly for its aesthetic qualities. It is perhaps not surprising that it continues to be used in artistic ways. See for instance Thomas and Helene Hoffmann's artistic partnership *Cryosity*. Retrieved 11 January 2024 from https://en.cryosity.com/.
33. Simpson, *North Ice*, 162.
34. Budd, Dingle, and Radok, "The Byrd Snow Drift Project," 80, 99.
35. Braun et al., "Making Futures by Freezing Life," 693–99; Gavroglu, ed., *History of Artificial Cold*; Radin and Kowal, *Cryopolitics*; Rees, *Before the Refrigerator*; Twilley, *Frostbite*.
36. "Protocol on Environmental Protection to the Antarctic Treaty."

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