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The Mushy Layer

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The mushy layer is where it all happens. And yes, that is the scientific term, despite it sounding like something a five-year-old might say. You know, the mushy layer: The banana destined for the compost. The wall spongy with mould. The wet spot. Life's messy chaos made visible if you can stand to look at it, which, frankly, most of us do not desire. I mean, who has the time between swiping and wiping and blitzing kale smoothies?

Scientists have largely overlooked not only the mushy layer, but the entire strata to which the mushiness is attached; that is, sea ice. The liminal zone separating ocean from atmosphere, sea ice regulates the heat exchange between our planet's largest elements, meaning it's a key part of the machinery stabilising the climate. This is particularly true of Antarctic sea ice, whose formation represents the planet's largest natural event in terms of area. That annual transformation of an expanse of the Southern Ocean twice the size of the continental United States (18–20 million square kilometres) from ice to water and back again plays a supersized role on global weather patterns. Despite all this, climate models still treat Antarctic sea ice as a "black box", which is akin to budgeting for a road trip without knowing the price of fuel.

For insight into this omission, let's start with descriptors like, "the South Pole of Inaccessibility" and "below 40 degrees south

there is no law; beyond 50 degrees south, there is no God" (the Antarctic lies below 60 degrees). Encircled by seas infamously roiled by the Antarctic Circumpolar Current (the world's strongest ocean current), Earth's southernmost continent is its coldest (recorded temperatures dive below -80° Celsius) and most remote land mass. Which is to say, this is a place whose truths will not be readily surrendered.

Which makes me think of North Korea. A land that hostile and complex human negotiations have made as unapproachable as geography has rendered the Antarctic. A sense of self-preservation staying any impulse to attempt understanding *that* situation. I mean, who wants to spend even a minute of their wild and precious life bogged down in the whys and wherefores of a country ruled by a triptych of 'Great Leaders' who continue to low-key hold the world hostage with opaque nuclear threats, and are famous for things like banning films from places whose actors were kidnapped to perform for Great Leader #2's personal gratification? Isn't life too short to voluntarily start nosing into questions whose answers—if they even exist—only catapult one into an infinitely blooming multiverse of other questions? It is!

But eventually the cost of ignorance might exceed the seeming impossibility of finding answers. And then what?

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Nucleation describes the formation of a first crystal, the start of something.

Because nature always seeks to conserve energy and maintain balance, you could say that doing nothing is, by one interpretation, the natural state of things (change is hard!). In the case of sea ice formation, inducing nucleation requires overcoming the ocean's energy stasis: either by dropping the temperature or introducing what chemists call an "imperfection"—something that can break the bonds of status quo, interrupt molecules that were all going about the business of being liquids until that first ice crystal managed to find a foothold from which to chill and invite friends to the huddle.

Foreign particles—a bit of sea junk, an edge of iceberg, an outcrop of land—are imperfections. Agitation—literally shaking things up—is also an imperfection, scientifically speaking.

By that (and other) logic, military occupation must be an imperfection: simultaneously shaking things up and introducing foreign particles. Whatever else you may say about it, war is undeniably the start of something.

The Korean War nucleated from the Cold War imperatives following the Second World War's expulsion of Japanese colonial powers from the Korean peninsula. Its footprint largely mirroring the 10th century boundaries of its ancient predecessor Koryo, Korea in 1945 had the bad luck to still share borders with Russia, China and Japan. In the post-WWII global shakedown, the American-Russian battle to control this strategic territory led to an afternoon in August when two US officers were given a few hours to draw the line that would delineate American from Russian "stewardship" of the Korean peninsula. Supposedly temporary, the 38th parallel North became the gash dividing one people into two nations. Over 70 years later the Koreas are still technically at war. A fracture visible from space, the undisturbed swath of green remains a no-man's land where Amur leopards, Siberian tigers and red-crowned cranes shelter; species too fragile to survive the hungers of our human world.

Crossing no land whatsoever and marking a different kind of no-man's land, the 60th parallel South distinguishes all the inhabited continents from Antarctica below. Defining the northern limit of the Southern Ocean, the latitudes south of the 60th—where winds exceed 145 kilometres an hour and whip up waves towering over five-storeys high—are described as the "Screaming 60s". But even those latitudes are not free from human meddle: the 60th serves as the northern limit of the Antarctic Treaty System, as well as the southern boundary of the South Pacific and Latin American Nuclear-Weapon-Free Zone.

While humanity's treaties and armistices and promissory notes are meaningless to the lifeforms going about the business of survival in the Screaming 60s, the 38th parallel's articulation was the beginning of

the end for Korea's inhabitants. The war that followed—killing nearly 10 per cent of the population—is sometimes called the "forgotten war". A moniker that begs the question, forgotten by whom? Certainly not the five to seven million Koreans who survived by scattering to all corners: a handful of jacks tossed across the hot pavement of a bored afternoon. I recently learned that Koreans still top the list of the most internally displaced people—on par with places like Syria and the DRC—a fact that provides context for the expulsion from South Korea of some 200,000 (maybe-probably-mostly-not-really) orphans for adoption to the West, of which I am one.

Growing up in America, I thought I knew what had happened to me, where I came from, who my people were. I was given pictures and names of biological parents who had died from causes—heart attack, cancer—I could grasp. I received letters from older brothers sent to Denmark for adoption; their *par avion* memories captured in a baroque Scandinavian cursive, scraps to quell any adolescent yearning to wonder further about my birth family. But then, later, I did wonder about a few things, and those questions led to the discovery that I was not in fact related to those brothers in Denmark: that their story was not mine, but belonged to some other girl, who remains lost to my brothers-not-brothers. My origins suddenly a black box.

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So what is it about Antarctic sea ice that is so mysteriously important?

Let's take a step back and recognise that in the rare instance that people think about sea ice, the image most likely to spring to mind is that of a sad polar bear stranded on a shrinking ice floe. But that tragic icon belongs to the Antarctic's doppelganger, the Arctic. While superficially similar, the two are, literally and figuratively, polar opposites. A Jekyll-and-Hyde, Jean-Grey-and-Dark-Phoenix situation. Santa, reindeer and polar bears versus penguins huddling to survive the annual death march.

First, the Arctic is an ocean (not a continent). Second, the Arctic's waters are calm—circumscribed by Europe and North America's

northern edges, it lacks the open ocean necessary to generate wave action. These conditions mean Arctic sea ice is thicker, longer lasting and less mobile. Antarctic sea ice by contrast is thinner, far more seasonal, spread out across a vast expanse, and dynamic in its formation. In other words, it's complicated.

Regardless of which pole it calls home, sea ice is frozen saltwater. Although the presence of salt hampers freezing (like a rattling window dooming your descent into slumber, salty ions disrupt water molecules' pull to bond into ice crystals), the Antarctic's winter temperatures (coldest place on earth!) and savage ocean churn provide the perfect conditions for imperfection when it comes to ice-crystal formation. But how the ice crystals agglomerate into millions of kilometres of sea ice is where the mushy layer comes in.

As the top (coldest) layer of ice forms, salt is expelled in brine channels that push ever downwards towards the (warmer) ocean water while the ice thickens up top. This perpetually descending slush—the mushy layer!—is made of ice crystals and brine, with the latter trickling in capillary-like fingers that flow into larger "streamers", which occasionally pool before moving again. A complex and dynamic theatre of heat and energy exchange, the mushy layer plays a vital but still poorly understood role in how ice, seawater and the atmosphere interact. Accurate modelling of the mushy layer is therefore critical to understanding how warming temperatures are likely to affect the formation and melting of Antarctic sea ice, which (largest natural event on the planet!) has a massive influence on the ocean currents, heat distribution and climate patterns that dictate life as we know it.

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"Ice is quite unforgiving at minus 30," the scientist said, referring to her studies on sea ice mechanics and the conditions that cause its fracture. Such information is vital to the integrity of the icebreaker ships that ferry Antarctic scientists into the Screaming 60s to conduct the research that will—hopefully, eventually—demystify

sea ice and mushy layer thermodynamics. With climate-related mega-events coming thick and fast, it may not be enough, but it's a start.

Truth can also be quite unforgiving—at any temperature.

For over a decade I chose to ignore the bleak implications of my brothers-not-brothers story. But then I nucleated, literally. Children being the ultimate imperfection, kicking your ass out of stasis. Eventually I learned that in order to facilitate my departure to America, my documents had been falsified, my family name literally excised from the note my birth family had tucked into the blanket that swaddled me. Rendered *adoptable*, I was put on a plane to the United States. A penguin shipped to the Arctic to be raised among polar bears.

Once considered the "Cadillac of international adoption", Korean adoption practice is now the subject of a Truth and Reconciliation Commission. Investigating the cases of over 350 adoptees who suspect foul play by adoption agencies, the process is happening in tandem with a handful of lawsuits filed by adoptees and one birth mother against adoption agencies and the South Korean state. The charges include negligence, fraud and human rights violations. Sparked by the bad press these cases have stirred, in 2024, the Netherlands closed its doors as a "receiving" country, and China (South Korea's only rival in terms of numbers of children sent for adoption) announced the end of its international adoption programme.

The painful truths animating all of these cases make clear why many prefer to leave the past undisturbed. While my own search has been filled with disappointment and mind-fuckery, it has equally nourished my soul in profound and unexpected ways. It also opened my eyes to a bigger picture in which I understand that we adoptees are the tip of the iceberg when it comes to the forced separations, displacement and intergenerational trauma suffered by Koreans—North and South—over the course of the 20th century. Reading the international news these days, I am frequently struck by how these dynamics continue to play out. Topping the list for the highest suicide and lowest birth rates recorded in the so-called developed

word, South Korea—in a panic about its shrinking population—nonetheless continues to send a couple hundred of children for overseas adoption annually. Change is hard.

I take strange comfort in sifting my way through these layers of grim context, which, while failing to yield anything like the specific answers I crave, also belie the power of the black box. That is, by starting to understand pieces of a story whose beginning I may never know, I can perhaps change the ending.

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Scientists used to think that the mushy layer's brine channels were static, stationary and predictable. More recent studies say not so: the bigger streamers can suddenly shut off. The smaller fingers can change course, moving the brine—with its friction and warmth—to melt an opposite channel; an ever-shifting meander that not only makes sea ice formation possible, but also acts as a nursery where microbial critters and nutrients flourish, stimulating phytoplankton blooms that attract and feed marine creatures from krill to penguins to whales. A whole food web, indifferent to human efforts to understand its inner-workings, thriving in the vast, glorious and ever-mushy crucible of life.