When ice grows up

A few months ago I joined the little-known fraternity of people who have opened their freezer doors, looked at their ice cube trays and said to themselves, "What the heck is *that*?"

Poking up from one of the partitions of my ice-cube tray was a needle of ice about 3 cm long and sticking nearly straight up – even though, as far as I could tell, all the gravity around me was pulling down.

My first thought was that something had dripped onto the tray from above, building up the spear of ice like dripping water builds up stalagmites on the floor of a cave. Nothing appeared to be thawing, but just to be sure, I moved aside some frozen chicken and a bag of peas and positioned my refilled ice-cube tray so that nothing was above it.

The next day brought another of the mysterious lances of ice.

At this point I did what any baffled student of science does today: I posted a photo on my blog. That was my introduction to the wonderful world of ice spikes. It turns out that several people have developed entire websites devoted to ice spikes. There are plenty of pictures, some short video clips, and a shared sense of what we all like best about science: getting to say to oneself, yet again, "Wow, isn't this cool?"

One of these sites (http://ow.ly/sdjjh) is run by Stephen Morris of the Experimental Nonlinear Physics Group at the University of Toronto. Morris's site contains tales of ice spikes developing in ice-cube trays, birdbaths and rivers downstream of a weir. There is even an amazing account from Pennsylvania's Harborcreek Historical Society of a man who, in 1963, walked 32 miles across a frozen Lake Erie and reported vertical ice "spurts" that "looked to him like telephone poles standing straight up all over the lake."

On the academic side, Morris's site also links to a paper on ice spikes that appeared in the *Physical Review* in 1921. In it, the author, one Herbert Grove Dorsey, reports, with pictures, on ice columns up to four and a half inches high. Dorsey had been thinking of ice spikes since he saw them on a tin pan of frozen water on 15 December 1916 in Gloucester, Massachusetts.

Another site, http://snowcrystals.com, has been put together by California Institute of Technology physicist Kenneth Libbrecht. He told me that he gets one or two e-mails a day – amounting to "thousands over the years" – from people who see ice spikes on a bird bath after a cold winter's night or, like me, in their ice-cube trays. (Technically, they should be called "ice parallelepiped" trays, but that's never caught on.) Anyway, one summer Libbrecht asked an undergraduate, Kevin Liu, to investigate ice spikes. After making several thousand ice cubes, Liu and Libbrecht found that the probability of ice-spike formation peaks at about –7 °C, at which point spikes form up to 35% of the time. The pair were able to increase this to almost 60% if they used a fan to circulate air in their freezer, and they also found that spikes form more frequently with mineral-free distilled water – something Libbrecht says he cannot explain.

Libbrecht and Liu published their work in the *Journal of Glaciology* and in their paper they report strong evidence for the so-called "Bally–Dorsey model" of ice-spike formation. (Bally published his work in the Swiss journal *Helvetica Chimica Acta* in 1933. Fascination with ice spikes knows no international boundaries.) This model suggests that as water in a container freezes, beginning on the surface and moving in from the edges, the expanding ice forces water through the remaining hole and up. This process creates a tube, frozen on the outside, in which liquid water travels upwards. The water then freezes at the top, thereby lengthening the tube until all the liquid is gone or the tube freezes shut. Libbrecht and Liu videotaped the formation of several spikes, and found they grew to their full height in 3–10 minutes, at a rate of "roughly" 50 μm per second. Some spikes even changed direction when disturbed, until their tubes froze shut.

I did what any baffled student of science does today: I posted a photo on my blog

For spikes to form in frozen liquids, the liquid must expand as it freezes. Water, which we take so much for granted, is one of the very few substances with this property. My research indicates that antimony and bismuth also expand as they freeze, but their freezing points are 631 and 272 °C, respectively. This suggests an interesting research programme for the next ambitious undergraduate – as long as their department owns a fire-proximity suit.

My own investigations were not nearly as hazardous. I was only able to form one more small, stubby spike about 1 cm in height, and, strangely, none at all using distilled water. But even for containers with a sizeable diameter of about 15 cm (such as my cat's feeding dish), the ice surface was rarely flat, and Libbrecht suspects this is due to similar forces on the liquid water as the surface freezes inward.

Naturally, every time I open my freezer door now, I hope to see another ice spike. Or something even stranger. Maybe this is how Heike Kamerlingh Onnes got his start.

David Appell is a science writer living in Oregon, www.davidappell.com

● Readers are invited to submit their own Lateral Thoughts. Articles should be 900–950 words, and can be e-mailed to pwld@iop.org