technologist, follows with an analysis of why starch and gelatin remain better at releasing flavours than xanthan and other thickeners.

There is a substantial report on the Turkish delicacy *salep dondurma* — sometimes known as fox testicle ice cream. It contains the ground roots of an endangered orchid, which are said to resemble fox testicles and give a stretchy, chewy consistency to the ice cream. A group at New York University shows that these properties come from the carbohydrate glucomannan, also found in Japanese konjac flour, which, unlike the orchids, is plentiful. Food-structure expert Tim J. Foster reveals that the stretchiness comes from phase separation of the glucomannan and milk proteins during freezing, a physical effect that can also be achieved by cooking. Expect to see stretchy savouries in modernist restaurants soon.

Other chapters propose making meringue-like solid foams from milk powder and tomatoes, flavouring ice cream with coffee extracted into butter to exclude its bitterness and acidity, and trapping aromas in mixtures of molten sugars. Intriguing but all too sparse are essays from chefs who explain how science contributes to their creativity.

However, I found the book somewhat parochial and not always an enjoyable read. The writing is often less than fluent, and frequent pronouncements about the value of food science become mind-numbing. Some chapters reinforce the image of the food scientist as a technician out of touch with cooks.

In rebutting writer Michael Pollan's denigrations of food science and technology, for instance, one chapter makes the astonishing claim that cheap processed foods are responsible for increased lifespans during the twentieth century. In another example, an encapsulation specialist searches for a quick way to make pizza dough because his mother's recipe takes 2–3 hours and he does not "have the luxury of time". He replaces the yeast with encapsulated baking powders, which most cooks can't buy, and notes that the mixed dough must be rested to hydrate — for 2–3 hours. An essay on the acoustic nature of crispness gives a recipe for a frying batter, then suggests that, to experiment with the recipe, the reader can "place the battered fish on the texture analyzer platen and record the force displacement and acoustic output as the probe pierces the batter".

Food scientists have much to contribute to today's dynamic food scene. I hope that those who write sequels to *The Kitchen as Laboratory* will shake the chips from their shoulders, work more closely with cooks and convey more of the joys of understanding and discovery — and eating. Tip: they should start with another big pinch of Kurti. ■

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K. LIBBRECHT

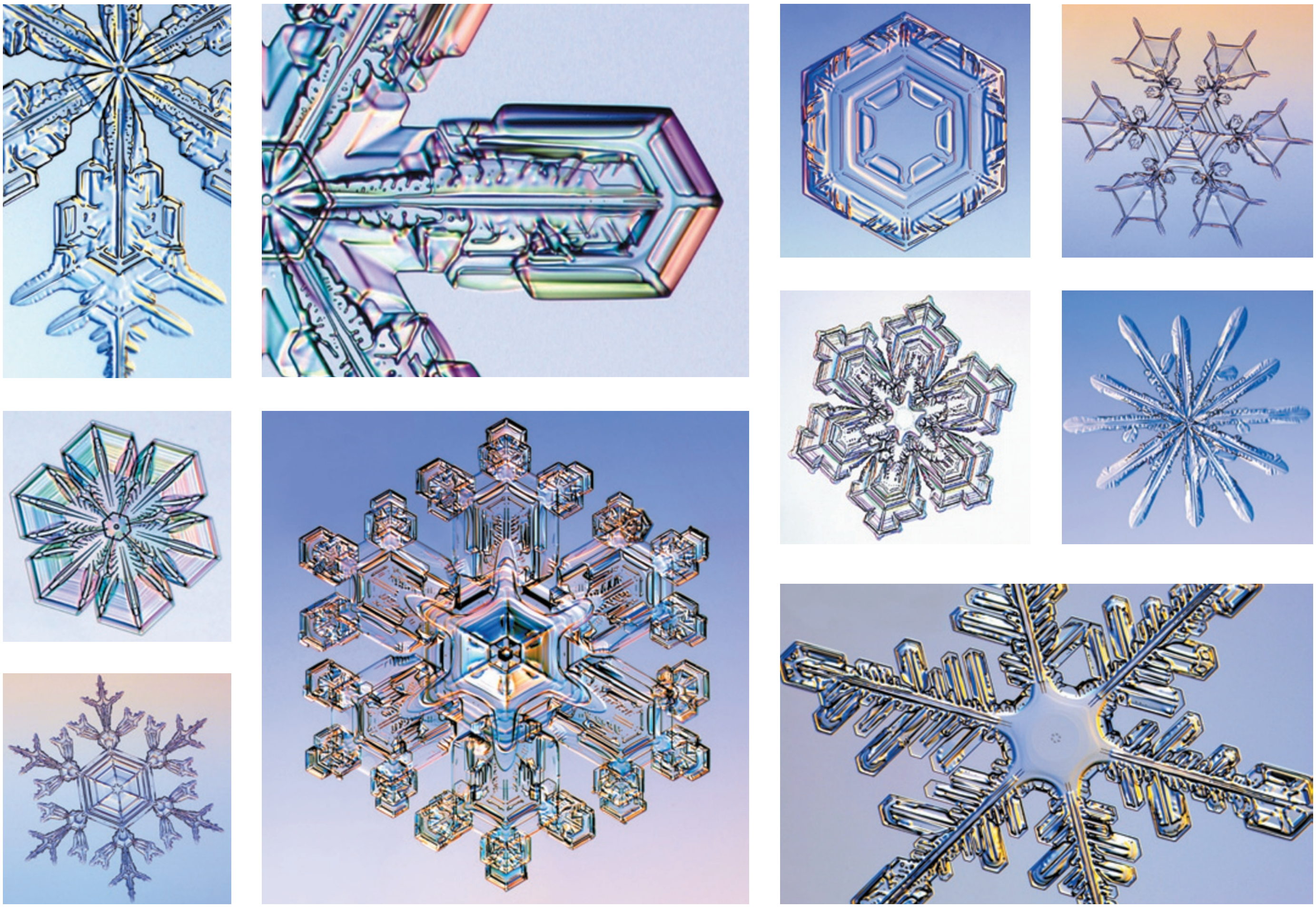
Q&A Kenneth Libbrecht
The snowflake designer

For the past decade, physicist Kenneth Libbrecht has been studying how ice crystals form, taking thousands of photographs of their intricate structures. He describes how he grows snowflakes in his lab at the California Institute of Technology in Pasadena, and never tires of tracking the real thing in the far north.

NICK HIGGINS

Why study snowflakes?
We see these beautiful structures falling from the sky, and we still cannot explain how they came to be. When you ask how snowflakes form, you are really asking about how molecules go from a disordered gaseous state to an ordered crystalline lattice. Unexpected phenomena can emerge — snowflakes are one fascinating example. The complex morphologies arise in part because different ice surfaces grow at different rates. What we learn could eventually find application in materials science or nanoscale self-assembly. But I am also motivated to simply understand how this natural phenomenon works. I use ice as a case study of crystal growth.

What sorts of shapes do you see?
The diversity of snow-crystal shapes is amazing, and you can learn a lot even with an inexpensive magnifier. You can find hollow columns, needles, bullet rosettes, stellar dendrites, sectored plates, ▶



K. LIBBRECHT

Fake or flake? Within this gallery of natural snowflakes are two designed and made by physicist Kenneth Libbrecht in his lab.[1]

12-branched stars, triangular crystals and many more. One of my favourites is the capped column, which looks a bit like two wheels on an axle. I grew up in snow country in North Dakota, but I never noticed capped columns until I went searching for them. Not every snowfall brings great snowflakes, but some days the crystals are spectacular.

And you're a snowflake photographer?
The physics came first, but I soon became hooked on snowflake photography as well. It is a bit of an odd hobby for someone living in southern California, I admit. My quest for photogenic snowflakes has taken me to Canada, Alaska, Japan, Sweden and locations in the frozen north, yielding more than 10,000 photos. Snowflake photography began in the 1880s with US farmer Wilson Bentley. I am continuing the craft, adding coloured lights and digital imaging techniques.

Why do snowflakes grow into such complex patterns?
A typical stellar snow crystal begins as a tiny hexagonal prism. The six-fold symmetry comes from the underlying symmetry of the ice crystal lattice. Because the six corners of the prism stick out into the humid air, the corners grow more rapidly, and eventually six branches sprout. The growth is very sensitive to temperature and humidity, which change as the crystal moves through the clouds. The six branches are exposed to the same conditions at the same time, so they grow in synchrony. The final product is a snow crystal that is complex and roughly symmetrical. And because no two snowflakes follow the same path through the clouds, each has a different pattern.

So no two snowflakes can be identical?
I grow simple hexagonal crystals in the lab and many look alike, although they are not identical at the molecular scale. The real question is: how many different ways are there to make a snowflake? With complex patterns, the possible variations can be enormous, easily larger than the total number of atoms in the Universe. So the probability of finding two snowflakes that look identical under a microscope is infinitesimal.

How do you make designer snowflakes?
In a chamber I make millions of little crystals, until one falls flat on a piece of glass. Then I start blowing humid air at it, which makes the crystal grow up in a mushroom-like shape. As it grows, I change the temperature and humidity to get plates, branches and other desired effects. There is another method using high-voltage electricity. Water molecules are polar, so strong electric fields around a crystal can lead to a runaway instability that produces thin needles of ice. We then grow designer snowflakes on the ends of the needles.

What problems are you working on?
I am especially intrigued by how ice growth changes with temperature. We usually think of snow crystals as thin, flat, star-shaped plates — the iconic snowflake shape. But often the crystals grow into slender hexagonal columns, the same basic shape as a wooden pencil. In fact, the overall shape changes from plate-like at −2 °C to columnar at −5 °C, then plate-like again at −15 °C, then back to columnar below −30 °C. This phenomenon was discovered by Ukichiro Nakaya, a Japanese physicist who pioneered the systematic study of snow crystals 75 years ago. But the origin of this odd behaviour is still not known, so I am working hard to solve this puzzle. ■

INTERVIEW BY JASCHA HOFFMAN

[1] Artificial snowflakes are at bottom left and top right.