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The enduring mystery of snowflakes

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This dendritic snowflake was created using a computer model developed by Janko Gravner at UC Davis and David Griffeath at the University of Wisconsin-Madison. Credit: Janko Gravner and David Griffeath

Who hasn't caught a snowflake in a mitten and marveled at its starlike detail, and then recalled that no two snowflakes are alike? But these crystals of ice are even more different than one might imagine - there are needle-like snowflakes, hollow-column snowflakes and flakes that look like delicate dumbbells, with two joined together by a column.

Caltech physicist Kenneth Libbrecht, who studies the crystalline structure of snowflakes and has published seven books of snowflake photographs, talked to the Los Angeles Times about what we do, and don't, know about them.

Q: What's so strange about snowflakes?

A: If you grow ice crystals - snowflakes - just below freezing, then you get thin plate-like crystals. These include the canonical snowflakes, the star-like crystals. But if you get a little colder, (around 5 degrees C below freezing) then instead of plates, you get long thin columns - which is really almost the opposite of a plate. Think wooden pencils, little hexagonal columns, as opposed to a hexagonal plate. In the star type, the faces grow slowly and the edges grow quickly, and in the pencil type, the edges grow slowly and the faces grow quickly.

And so in just a few degrees' temperature change, the growth changes from plate-like to columnar. And as you go colder, to 15 degrees below zero, it changes back to plate-like.

At even lower temperatures, below 30 degrees below zero, the shape changes back to columnar.

So there are these transitions as a function of temperature, and that's really hard to explain. It's been a puzzle for 75 years, and it's still really not known what causes this.

There are also variations in humidity. And the higher the humidity in the clouds, the faster the crystals grow, and the more structure they develop and the bigger they get. So at low humidities, you get simple, small crystals and at high humidities, they're more complex.

Q: In your lab experiments, what have you been able to find out?

A: What I found is that there's what I call a "sharpening effect." When the edge of an ice crystal gets sharp, actually the molecular structure of its edge changes, and it makes it grow faster, which makes it sharper, which makes it grow faster, and which sharpens it more ... so you end up with a very thin plate as sharp as a razor blade. That sharpening effect is why the crystals are so thin and flat.

So if you change the temperature, all you're doing is changing the way the sharpening effect works. If the sharpening effect goes in the edge direction, it'll make a thin plate. If the sharpening effect goes in the upwards direction, you get a hollow column. A very small temperature change can make it flip directions. The sharpening effect amplifies that small change.

Q: Why is every snowflake different?

A: As an ice crystal falls, it will move from one part of the cloud to another, and the temperature and the humidity will be changing as it falls. Every time there are these small changes in the conditions, the growth of the arms changes. So you get all these branches and facets and all these different shapes - and by the time it lands on the ground, it's had a very complicated history because of all these changes in temperature and humidity. And because no two crystals follow exactly the same path as they fall, they all look a little different.

Q: So snowflakes come in more shapes than your garden-variety hexagon. Which is your favorite?

A: One of my favorites is the capped column. That's a crystal that first forms as a column and later on it changes, and has plates on the ends of a column. So it's an odd looking thing - like two wheels on an axle.

When I started reading the literature on the subject, I found pictures of these capped columns and just found them really interesting. I mean, I grew up in North Dakota - how come I've never seen one of these before? On a trip to visit family at Christmas time, I took along my magnifying glass and I went outside and looked and the falling snow - and there they were, capped columns all over, and these other shapes, too. You just don't notice if you don't pay any attention.

That's what got me into popularizing the science of it, because it seemed like if you live in snow country you ought to know a little a bit about what's falling out of the sky.

Q: Are there advantages to studying ice crystals rather than other, perhaps more exotic, materials?

A: Not only is the physics of ice crystals particularly rich, but experiments are pretty cheap and easy. As you can imagine, ice doesn't have a lot of safety issues. For almost anything else you can think of growing, experiments are confounded by safety issues. Just about any chemical has hazards, so you have to spend a lot of money and time worrying about that.

I just love the ability to be able to pour your experiment down the drain or just evaporate it into the air without any thought of safety.

And the fun part is, in the end, it's not like some esoteric thing that nobody ever sees. Most physicists study black holes or Higgs bosons - things that that never appear in ordinary experience. Whereas this stuff falls out of the sky, literally. So it's kind of fun to think about the puzzles surrounding it.

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