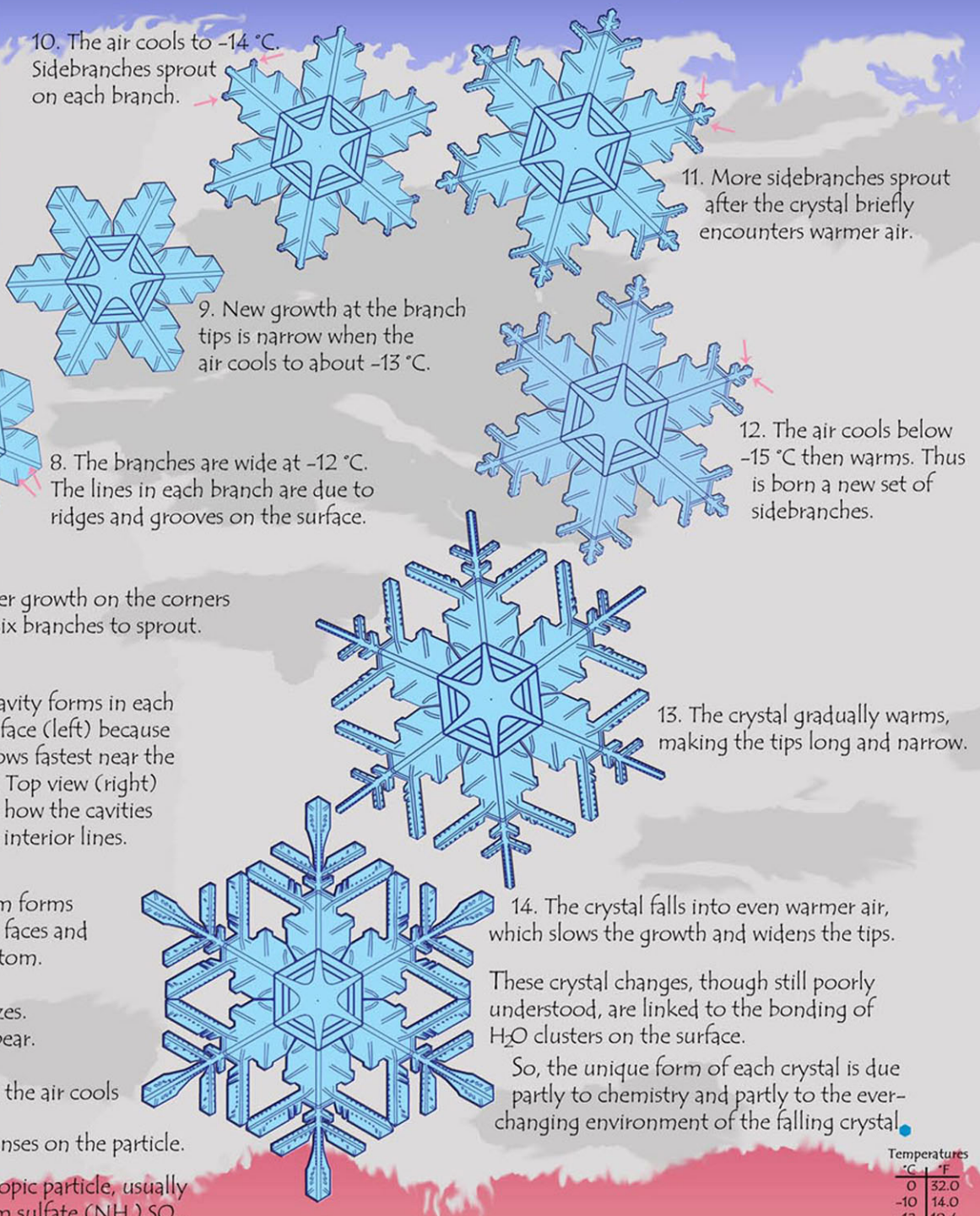
The crystal chemistry of snowflakes

Ice, Nature's simplest hydrogen-bonded crystal, makes surprisingly complex forms

Complex forms arise from many small changes. The changes are thought to originate from clustering of H_2O molecules on ice surfaces. Here's a possible set of changes.



10. The air cools to -14 °C. Sidebranches sprout on each branch.

11. More sidebranches sprout after the crystal briefly encounters warmer air.

9. New growth at the branch tips is narrow when the air cools to about -13 °C.

12. The air cools below -15 °C then warms. Thus is born a new set of sidebranches.

8. The branches are wide at -12 °C. The lines in each branch are due to ridges and grooves on the surface.

7. Faster growth on the corners cause six branches to sprout.

13. The crystal gradually warms, making the tips long and narrow.

6. A cavity forms in each prism face (left) because ice grows fastest near the edges. Top view (right) shows how the cavities create interior lines.

5. Now a prism forms with six prism faces and a top and bottom.

14. The crystal falls into even warmer air, which slows the growth and widens the tips.

These crystal changes, though still poorly understood, are linked to the bonding of H_2O clusters on the surface.

So, the unique form of each crystal is due partly to chemistry and partly to the ever-changing environment of the falling crystal.

4. The drop freezes. Crystal faces appear.

3. The drop grows as the air cools

2. Water vapor condenses on the particle.

1. (stage 1) A microscopic particle, usually containing ammonium sulfate $(NH_4)_2SO_4$, rises into the cloud.

(Drawings not to scale.)

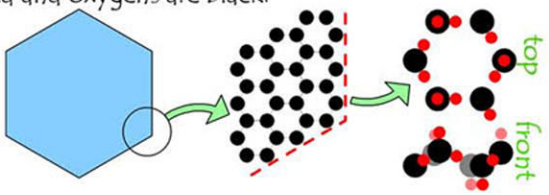
Temperatures	
°C	°F
0	32.0
-10	14.0
-12	10.4
-13	8.6
-14	6.8
-15	5.0

How does snow get like that?

A typical snow crystal starts from a frozen droplet,then becomes hexagonal, and then sprouts six branches. The form continues to change as the humidity and/or temperature of the surrounding air changes. The 14 stages above is just one of many possible sets of changes.

Why 6?

The six sides come from the corners of the hexagon (e.g., stage 7). The hexagon shape is possible because the H_2O molecules chemically bond into a hexagonal network (below). On the right side, hydrogens are red and oxygens are black.



Are no two alike?

The old adage 'no two alike' may well be true for crystals of the size in stage 14 above, if we look close enough. But the adage may be false for crystals that fall out before stage 7. Regardless, one thing is clear: snow has tremendous diversity. This diversity is partly due to the very high sensitivity of growth to tiny temperature changes.

Courtesy of Jon Nelson (Sci-cubed & Ritsumeikan University)