Stars of Snow

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"Hast thou entered into the treasures of the snow?
Or hast thou seen the treasures of the hail?"
Job 38:22

A number of years ago, I produced a Christmas card which featured a snowflake in the unusual form of a Christmas tree. To enhance the suggestion of "evergreen", I photographed it by transmitted light with a green filter (Wratten No. 58) in the light path. It has been almost twenty years since the card appeared, and in that time I have had many occasions to project the original 35-mm transparency. When I do show it, I mention that particular snowflake was captured during a snowfall in Chicago on January 17, 1971. Inevitably, there is both skepticim, and a desire to know "what's the trick?" As the question has again come up, I have decided – unlike the good conjurer – to reveal the trick: do not try to deal with the actual, individual snowflake, as "Snowflake" Bentley did over a hundred years ago, but make an exact plastic replica, so that the preserved form can be studied and photographed at leisure.

How to Make Replicas of Snowflakes ❄

I learned how to make snowflake replicas in 1964 from P.J. Hoff, a television weather forecaster for Chicago's WBBM-TV. P.J. Hoff was also an excellent cartoonist, and his weather presentation was based on a hand-drawn map which featured his little cartoon characters which were made to move in clever fashion. On one of these shows, P.J. Hoff showed a snowflake collection, and I wrote to him suggesting that he make the preservation method available to science teachers – and this he did. I learned later that the technique had actually been developed by Vincent I. Schaefer while at the General Electric Company and had been described by him in several publications during the early 1940's[1-3]. The method occurred to him during the winter of 1940, and, thus, it has been practiced for a half century.

You will need very few materials:

1) A solution of polyvinyl formal resin dissolved in ethylene dichloride
2) A supply of clean microscope slides
3) A paint brush
4) Black velvet (optional)

The plastic, polyvinyl formal resin, is made by Shawinigan Resins Corporation (Springfield, MA) a subsidiary of Monsanto, under the name Formvar 15/95E. I received my sales sample from Monsanto's Chicago Service Center.

Ethylene dichloride, a commonly used solvent, can be obtained from any science supply house; it may be found under the name, 1,2 Dichloroethane. Reagent or Analytical grade is not necessary; Practical grade is less expensive and perfectly adequate.

Make up a 1% to 3% solution of the plastic in solvent; this can vary a little and is not critical. You will be able to tell if the solution becomes too thick through evaporation. You may like to have two consistencies for different-size flakes – the 1% solution is good for thin, delicate flakes, and a 2-3% solution is best for larger flakes. Put the solution up in l oz or 2 oz bottles; I use a 1-oz amber bottle with glass dropping rod.

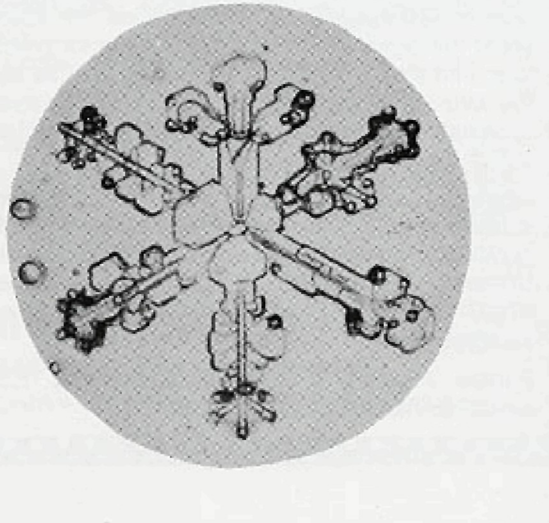
I keep my solution, a brush, and a supply of microscope slides in the refrigerator all of the time, because you never know exactly when you will need them. All snowfalls are not alike; around Chicago there are only 5 or 6 per season when all of the flakes are <u>perfect</u> and they seem to fall in slow motion – you will not notice this if you are driving through masses of it in homeward-bound traffic, or if you are shoveling a 100-ft driveway! At any rate, should you notice this kind of fall, where each flake individually sparkles at you and takes its time falling, put on a dark coat and your galoshes, grab your materials from the fridge, and go out to a sheltered place – shed, garage, eaves.

Place a drop or two – or – three of the plastic solution on a microscope slide, and spread it evenly into a thin layer all over the slide, using the side of the dropper. Now step into the falling snow with one arm bent in front of you so that the flakes fall on your dark sleeve. With the brush, pick up the flakes you want and gently place them in the solution on the slide. Do this repeatedly until you have many flakes on the slide. Next, keep the slide outdoors, but protected from falling snow. The solvent will evaporate slowly, and before long you will have the snowflake sitting in hardened plastic. When you bring the slide indoors, the snowflakes will melt, but you will be left with permanent plastic replicas.

A hundred years ago, Bentley collected his snowflakes on a black tray; others since have suggested 2 sq. ft. of black velvet on a board; I find it more convenient to use the sleeve of a dark coat. Bentley used a broom splint and feather to handle individual flakes; others suggest a glass rod or wire. I use a No. 0 watercolor brush. It doesn't matter – they all work.

What to do With Your Snowflakes ❄

Collecting snowflakes is an excellent family activity, and the results can be immediate. By the time you get your coat off and the microscope set up for projection, the melted snowflakes will have evaporated and the replicas on the slides are ready. Place a right-angle prism on your eyepiece so as to project the image on a screen or white wall, and select low-magnification objectives. Go from snowflake to snowflake using colored filters in the light path, and don't forget Rheinberg illumination and darkfield for spectacular effects; Nomarski differential interference contrast and transmission interference after Jamin-Lebedeff are also very nice, but not likely to be on your home microscope.



https://doi.org/10.1017/S1551929500069467 Published online by Cambridge University Press

My snowflakes have had their television debut. There was a Chicago television series known as Backyard Safari – it was a science program for youngsters, shown on Saturday mornings. The producers of the show were doing a program on ice and snow, and having seen my Christmas card, asked if I could bring my collection to the studio – which I did, along with my microscope and a few accessories. I set up and everything was ready to go; however, the large studio cameras was unable to be tilted vertically, and the producers were unable to come up with a solution to the problem. I pointed to a spot in space and told the camerman to focus on my finger, which he did. I then put my right-angle prism on the eyepiece and projected an aerial image in the same plane where the camera was focused. Voila! Instant success. I rotated the stage, moved from flake to flake, changed filters, and otherwise animated the flakes. It was a very successful program.

History of Snowflake Observation ❄

Aristotle was one of the first in the West to mention the formation of snow crystals, but the first graphical representation of snowflakes was that of Olaus Magnus, the Archbishop of Upsala (Sweden). Magnus included a woodcut of twenty-three snow crystals in his book on natural phenomena, published in Rome in 1555. However, the earliest reference I have to the microscopical observation of snowflakes is that of Hooke. In 1665, Robert Hooke described and illustrated snowflakes in his book, *Micrographia*[4]. He suggested exposing a piece of black cloth or a black hat to the falling snow as a means of collecting them. By naked eye he observed that they were all very regular figures and usually branched out with six principal branches, but by:

> Observing some of these figur'd flakes with a *Microscope*, I found them not to appear so curious and exactly figur'd as one would have imagin'd, but like Artificial Figures, the bigger they were magnify'd, the more irregularites appear'd in them; but this irregularity seem'd ascribable to the thawing and breaking of the flake by the fall, and not at all to the defect of the *plastick* virtue of Nature.... I am very apt to think, that could we have a sight of one of them through a *Microscope* as they are generated in the Clouds before their Figures are vitiated by external accidents, they would exhibit abun dance of curiosity and neatness... I think it not irrational to suppose that these pretty figur'd Stars of *Snow*, when at first generated might be also very regular and exact.

When one sees published photos of snowflakes they are usually those selected for their symmetry and perfection. Hooke notes that in fact none is perfect if magnified sufficiently. Also, flakes that collide during their fall may have broken branches, or if they link during growth there will be inhibition of growth on certain branches, just as when chemical salts are recrystallized. I have included illustrations of these less-than-perfect flakes because I think they are just as interesting as the perfect ones, and there are things to be learned from them-as one learns about perfect diatoms from studying broken frustules.

Almost a hundred years after Hooke, Henry Baker was reporting on his and others' observations in his 1754 book on the microscope[5]:

> The *Flakes* of *falling Snow* are various in their Configurations, and extreamly beautiful, if examined before they melt: Which may easily be done by making the experiment in the open freezing Air. DESCARTES, Dr. GREW, Mr. HOOK, Mr. MORTON, Dr. LANGWITH, and others, have given us several of their different Star-like Forms and Dr. STOCKE, of Zealand, have lately communicated to the Royal Society some new Figures observed before.

And then there was Bentley. In 1880, when Wilson A. "Snowflake" Bentley was a young boy of 15, his mother showed him a microscope she had used in her school teaching. It changed his life. He examined everything, but what fascinated him most was the infinite variety of snowflakes that fell from the Vermont skies. For three years he spent many days examining and making hundreds of drawings of snow crystals in a cold room at the back of the farmhouse. One day he read about a bellows camera that could take pictures through a microscope. He ultimately obtained the camera and some dry plates with his parents' help, and proceeded to make his snowflake camera. Working outside in a shed, he pointed his camera toward the sky to obtain transmitted-light photomicrographs. Depending on magnification and the amount of light, his exposures ranged from 10 to 100 seconds. His first successful photomicrograph was made in January 1885. He was still photographing snowflakes almost fifty winters later. Bentley photographed thousands of snowflakes. It's amazing that since he preferred his snowflake photos to appear against a black background, he laboriously cut out each individual snowflake from the negative, carefully following the outline of each crystal.

In the meantime, Hellmann's book on snowcrystals[6] was published in Berlin in 1893. This book contained reproductions of a number of photomicrographs, and a summary of all that was then known about snow crystals.

Bentley's book *Snow Crystals*[7] was published by McGraw-Hill in 1931, and Dover reprinted it in 1962. The book is illustrated with almost 2,500 photomicrographs of snow crystals, dew, frost, and hail.

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Stars of Snow

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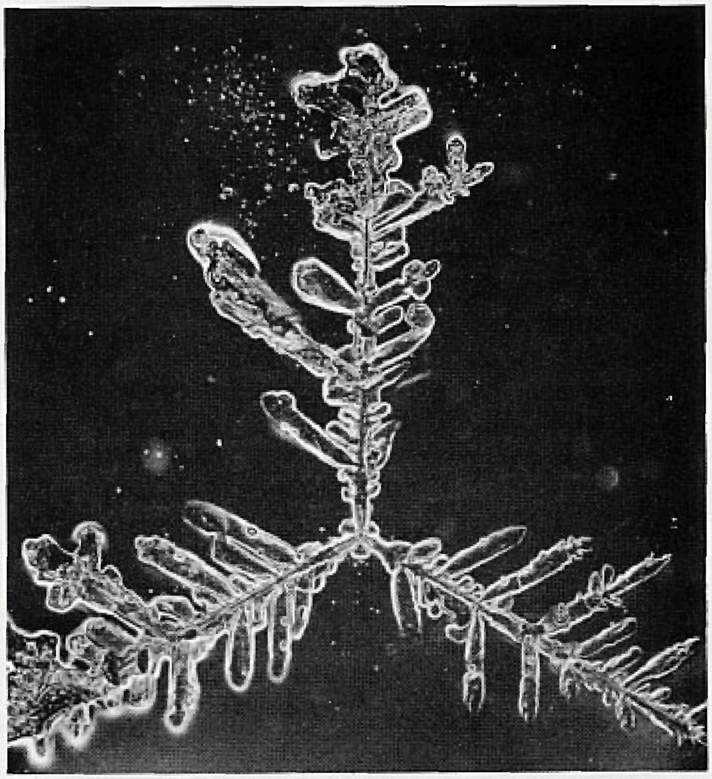
Microscopical Characteristics ❄

Schaefer estimated that "...during a single 10-inch fall of snow more than a million flakes may gather on a 2-foot square...." We read that no two snowflakes are exactly alike, but only microscopists have a true appreciation of the magnitude of this statement – form on endless form. Atmospheric scientists classify snowflakes based on morphology. They use a long and cumbersome scheme involving categories such as "hexagonal column, usually three to five times longer than thick", "Triangular plates-with extensions," "twelve-sided plates", etc. The standard chart used by meteorologists to classify snow crystals contains eighty different categories; for example, "P Seven a – radiating assemblage of plates" and "CP Three c stellar crystal with scrolls at ends." As might be expected, there is one category titled, "Miscellaneous"!

Optically, snowflakes are especially interesting. Ice belongs to the hexagonal crystal system. We know that complete crystals are rare, but that the skeletal crystals (snowflakes) usually form as basal tablets, hexagonal stars, and dendrites. In 1940 it was determined that the hardness increases with decreasing temperature, from H. 1.5 at the freezing point, through H. 4 at -44° C, to H. ~6 at -78.5° C (That's why snowballs go through windows easier when it's colder!). Snowflakes have a specific gravity of 0.918. In 1917, Ehringhaus determined that ice is uniaxial positive with $\varepsilon = 1.3091$ (D) and $\omega = 1.3104$ (D). The birefringence, therefore, is (+) 0.0013, which doesn't seem like very much, but it can actually cause observational problems – especially when employing the first-order red plate – when using a cold stage, if the nitrogen and chamber are not absolutely dry.



Winchell reports that under varying high pressures six other crystal phases of water are known; one is cubic, one tetragonal, and a third is orthorhombic.

Your rewards for collecting snowflakes in the bitter cold will be countless hours of pleasurable viewing –especially in July and August. And don't forget to include the children when you collect and look at snowflakes, for your greatest reward will come from sharing with them the wonders of these little Stars of Snow.

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