The History of the Science of Snowflakes

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The extraordinary beauty of snowflakes has captivated the curiosities of children and adults alike for centuries. Fascination with these white structures only intensifies upon closer examination of their diversity and structural complexity. This interest has sparked the interest of writers, poets, philosophers, mathematicians, scientists, and photographers throughout history. The field of snowflake science slowly emerged over time, beginning with the early philosophers who were first to ponder about how the complex shapes of snowflakes came about. The helpful observations made by some of the great minds of science, such as Johannes Kepler, René Descartes, and Robert Hooke, follwed. Later, major contributions to the field were made by a rural Vermont farmer commonly known as "Snowflake Bentley," while the works of Ukichiro Nakaya gave the conclusive scientific explanation of snowflake formation and morphology that is widely accepted today.

Perhaps the earliest documented observations on the six-sided shape of snowflakes came from ancient China. In 135 B.C., Han Ying wrote in his book on the Moral Discourses of the Han Text that "Flowers of plants and trees are generally five-pointed but those of snow are always six-pointed." Around A.D 525, the Chinese poet Hsaia Tung observed in one of his poems that "the ruddy clouds float in the four quarters of the cerulean sky, and the white snowflakes show forth six-petalled flowers." In the twelfth-century, the famous Chinese philosopher Chu Hsi noted, "Six generated from the Earth is the perfected number of Water, so as snow is condensed into crystal flowers, these are always six-pointed." These early Chinese observations marked the beginnings of the study of snowflakes (Mason 1966)

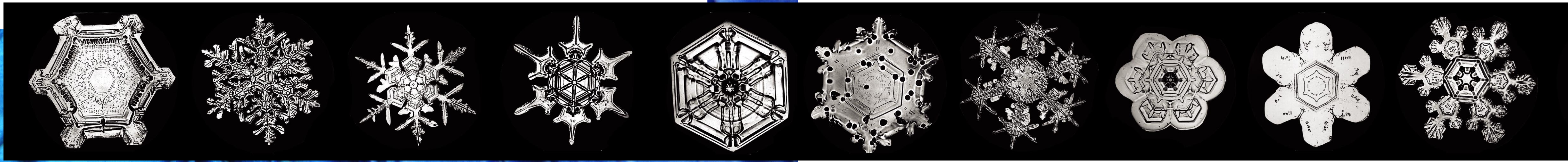
One of the first scientific references to the structure of snowflakes in European literature came from Johannes Kepler, considered by many to be one of the greatest scientists who ever lived. In 1611, Kepler published a short Latin treatise entitled *De Niue Sexangula*, or 'On the Six-Cornered Snowflake.' The treatise entailed Kepler's observations and thoughts on snowflake formation and shape. The *De Niue Sexangula* was his attempt to explain the hexagonal structure of snowflakes at an atomic level, although he failed to offer any concrete conclusions. Kepler recognized that the hexagonal symmetry observed was a common characteristic of all snow crystals despite the different designs each formed. He also considered the mechanisms of the growth of snow crystals and the different factors that ultimately determined their shape and size, specifically, why the snowflakes always exhibited hexagonal symmetry. Kepler finally realized that he was unable to arrive at an adequate answer for his. He remarked that he had "knocked on the door of chemistry" by embarking on this new science and therefore later challenged others to carry on his investigations, ultimately marking the beginning of the fields of snow crystal science and crystallography (Kepler 1966).

Other scientific minds later continued to make contributions to the study of snowflakes. René Descartes, a famous philosopher and mathematician, soon picked up where Kepler left off. In 1635, Descartes published *Meterologia,* in which he reaffirmed some of Kepler's early observations on the hexagonal symmetry of snowflakes. Descartes was the first to give detailed descriptions and remarkably accurate visual representations of snowflake morphology solely through the use of the unaided eye. His studies included drawings and observations of rare snow crystal formations, including twelve-sided snowflakes, stellar crystals, and those consisting of hexagonal columns with plated ends, commonly known as capped columns. Descartes was also intrigued by the precise hexagonal symmetry of snowflakes. He proposed that they resulted from an initial, uniform packing of irregular crystals. Descartes hypothesized that the disordered protrusions or arms of the snowflake melted to spread liquid throughout the crystalline structure of the snowflake thereby filling up the structural irregularities to form a flat, symmetric, and regular structure. Although inaccurate, Descartes' work helped give rise to the first correlations between atmospheric factors and snowflake formation as well as reaffirming Kepler's early observations of the interrelationship between hexagonal morphology and uniform packaging of crystalline particles (Mason 1969). In the seventeenth century, the invention of the microscope revolutionized science. Robert Hooke, one of the first men to construct a reflecting microscope, was able to make significant contributions to science through the aide of his microscope. In 1665, Hooke published his book, *Micrographia*, in which he exhibited details of microscopic phenomena. Besides making the famous discovery of the "cell" as the functional unit of life, he was also able to observe and illustrate the structural intricacies of snowflake morphology. Hooke noticed in particular how the side-arms or "leaves" of snowflakes branched and protruded parallel to the main branch. It is this complex branching that causes a snowflake to be feathery or fluffy. Hooke's more detailed illustrations therefore exposed the imprecision of earlier illustrations of snow crystals.

Wilson A. Bentley wrote himself down in snowflake science history in the early twentieth century. He is known many people throughout the world as "the Snowflake Man" or simply, "Snowflake Bentley" (Stoddard 1985). Bentley was a farmer who resided in the rural city Jericho in northern Vermont. Bentley's intense interest in snowflakes led to his more recognized profession as a researcher and pioneer in photomicrographical studies between 1885 and his death in 1931. Bentley used a self-made camera microscope to become the first person to photograph a single, unique snowflake. Throughout his forty-seven years of study, Bentley photographed over 5000 snowflakes, eventually publishing *Snow Crystals,* which contained a collection of more than 2000 of his photographed snowflakes. Wilson A. Bentley's work confirmed that "no two snowflakes are alike" (Martin, 1998).

Similar to Bentley, Descartes was so convinced of the unique symmetry of snowflakes that he asserted, "It is impossible for men to make anything so exact" (Mason 1966). In the 1950s, Ukichiro Nakaya proved Descartes wrong by successfully growing artificial snow crystals in the laboratory. Nakaya was a nuclear physicist who began his work on snow crystal formation in 1932 only after he failed to find a facility in his trained profession of nuclear research. Nakaya discovered that the shapes of snowflakes are determined by the conditions in which they grow, such as temperature and super-saturation of air. Nakaya's research focused on the dendritic crystal growth of snowflakes' leaf-like structures. Snowflakes with these structures possess a "fluffy" morphology, while snowflakes lacking these structures exhibit a plain, simple, and hexagonal morphology, which makes snow more dense and slippery (Nakaya 1954). Consequently, Nakaya's research has proven advantageous to meteorologists and those who predict high-risk avalanche areas. His research has helped equip these individuals with more knowledge of the properties of different types of snow.

Nakaya's research also offered the first concise explanation as to how snowflakes come into being. Although the terms "snowflake" and "snow crystal" are



courtsey of the Jericho Historical Society http://www.snowflakebently.com used interchangeably, snowflakes are in fact intricate structures composed of smaller sub-structures called snow crystals, which are in turn derived from conglomerates of ice crystals. The ice crystals themselves are formed when water molecules aggregate into hexagonal structures. The hydrophilic properties of water naturally cause the water molecules to attract to one another in this six-sided formation. Ice crystals nucleate around tiny particles in the air, such as salt or dust, to form snow crystals. As the snow crystals fall to the earth, additional snow crystals accumulate, ultimately form snowflakes. The distinctive morphology of the snowflake is shaped as the snow crystals pass through different air temperatures, wind patterns, and humidity levels. Changing any of these conditions can significantly modify the shape of the snowflake. Indeed, highly complex snowflake morphologies indicate correspondingly complex migration histories, and since no two snowflakes take the same path in their decent, it is highly unlikely that any two snowflakes will ever be alike (Nakaya 1954).

The mystery of the hexagonal morphology of snowflakes was finally solved three hundred years after Kepler first proposed the question as a challenge to the scientific community. Nature has long been a sense of intrigue for many, and thanks to the contributions of individuals like Kepler, Descartes, Hooke, Bentley, and Nakaya, we now know why each snowflake has a truly unique story to tell.

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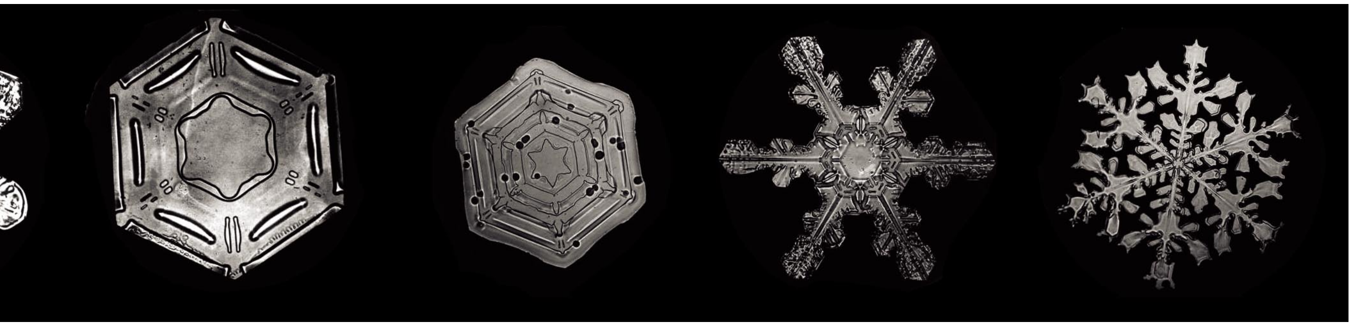

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