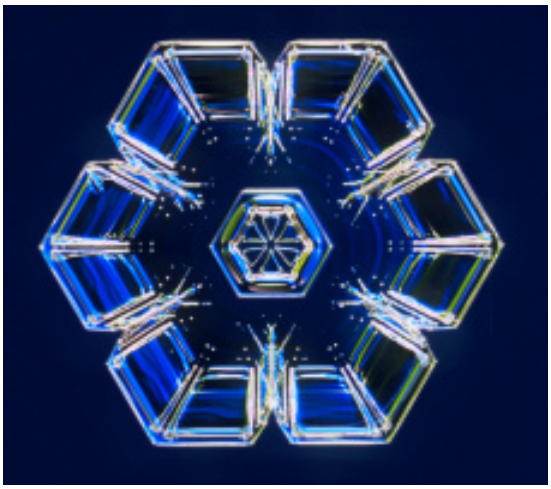
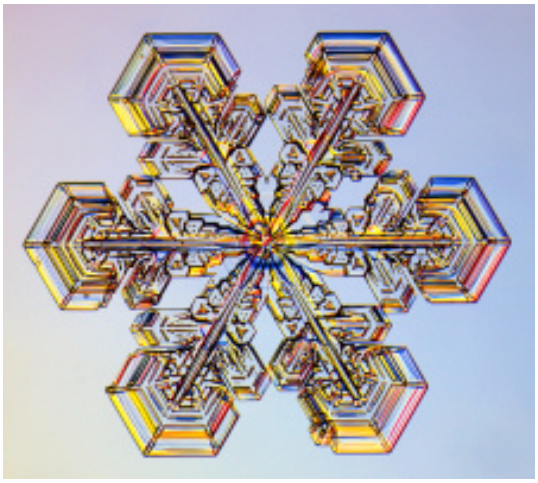
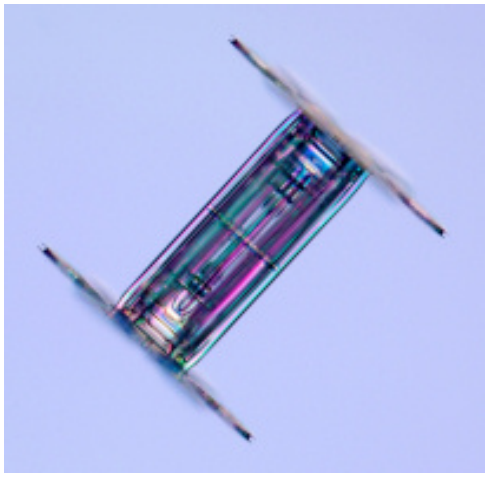


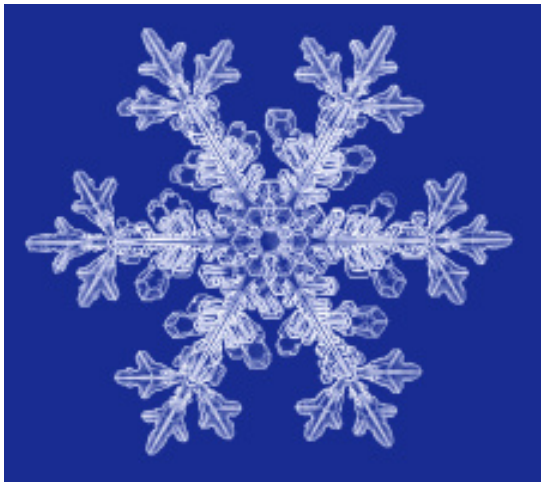


Crystallization of Water Vapor: What May We Discern From a Snowflake

Snowflakes are a thing of beauty. Why do we find them beautiful? And what do they teach us of the physical world? This paper will summarize what we know about snowflakes as scientists. We will also acknowledge our current state of ignorance about this phenomena.

The roll snowflakes have played in our history is profound. In literature, both poetry and prose, snowflakes are evocative and compelling instruments of description that finds immediate resonance with any reader with or without snow experience. In art we find the individual flake symmetrically soothing, pointing to an order we appreciate and as snow a season and mood setting technique. Theologically and philosophically it is the stuff of snow, water, that is used symbolically for life and death and many things in between in many belief systems and traditions. The contemplation of a snowflake may lead the observer into many avenues; some physically practical while others are playful or romantic imaginings. A snowflake has the potential to teach us a lot and perhaps inspire us even more.





"Water is the most studied material on Earth but it is remarkable to find that the science behind its behavior and function are so poorly understood (or even ignored), not only by people in general, but also by scientists working with it every day. "(Martin Chaplin PhD, 1) Water is composed of two **atoms** of hydrogen, the most ubiquitous element in the universe, and one **atom** of oxygen, the most abundant element on our planet. Most scientists would probably rank water, very high on the scale of wondrous molecules. Dr. Chaplin's website lists seventy-three anomalous properties of water (1). On examining what is known about the two gases, hydrogen and oxygen, alone, it is doubtful that today's science would predict water, a liquid, could exist. (3)

Water has three phases: solid, liquid and vapor. This discussion will focus on the transition from vapor to solid (crystalline) phase—snowflakes! Frozen liquid water falling from the sky is sleet. It is only when clouds containing supersaturated water vapor (i.e. excess of 100% humidity) encounter temperatures at or below 0° C (32° F) that snowflakes are formed. Figure 1 is a morphology diagram (referred to as the Nakaya Diagram, after the Japanese physicist Ukichiro Nakaya) often found in books and websites published by Kenneth G. Libbrecht, PhD. Dr. Libbrecht is the antithesis of the scientist described by Dr. Chaplin. Dr. Libbrecht is also chairman of the Department of Physics at The California Institute of Technology and the generous source of much of the science of snowflake information presented in this paper (see References).

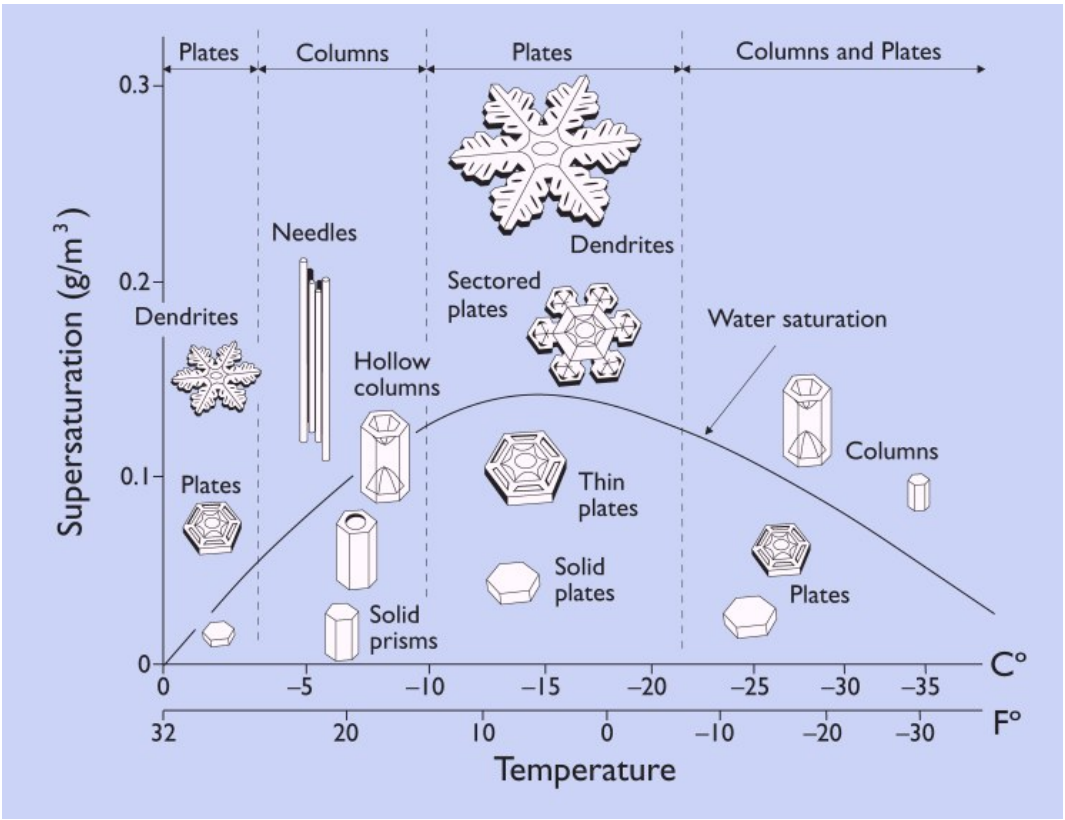


Figure 1.

Snowflakes, although generally hexagonal (six sided), exhibit a variety of morphologies--armed, branched, or faceted. The ultimate snowflake morphology starts with a molecule of water. Water is one of the most stable molecules known. The stability is because of what each element, oxygen and hydrogen, brings to the molecule. The electron orbital theory describes how electron pairs orbit around the nucleus of an atom. The first orbit can contain at maximum two electrons, one pair. Having two electrons in the first orbital lends stability but hydrogen only has one. Oxygen has eight electrons: two in its first orbital and six in the second orbital. But the second orbital can contain eight electrons for maximum stability. So when one oxygen and two hydrogen atoms come together, or bond, each hydrogen now has two electrons in their first orbital shell by sharing an electron pair with the oxygen. The oxygen now has a total of eight electrons in the second orbital shell because of this sharing with the two hydrogen atoms. This sharing of electron pairs is called a covalent chemical bond.

In H_2O, only two of the six outer-shell electrons of oxygen are used for this sharing, leaving four, non-shared electrons, which are organized into two non-bonding pairs.

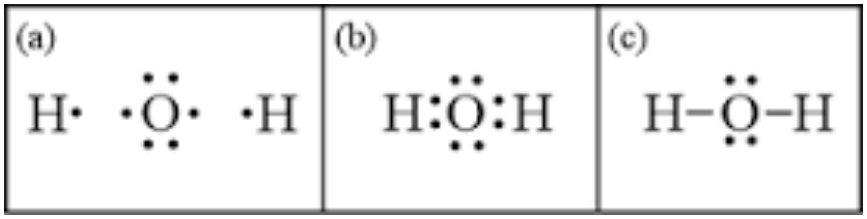


Figure 2. Cartoon referred to as a Lewis dot structure. When hydrogen and oxygen combine to form water. The solid lines (c) represent the covalent chemical bond. (2)

The four electron pairs surrounding the oxygen tend to arrange themselves as far from each other as possible in order to minimize repulsions between these clouds of negative charge. This would ordinarily result in a tetrahedral geometry in which the angle between electron pairs (and therefore the H-O-H *bond angle*) is 109.5°. However, because the two non-bonding pairs remain closer to the oxygen atom (because they are not "sharing"), these exert a stronger repulsion against the two covalent bonding pairs, effectively pushing the two hydrogen atoms closer together. The result is a distorted tetrahedral arrangement in which the H—O—H angle is 104.5°. (3)

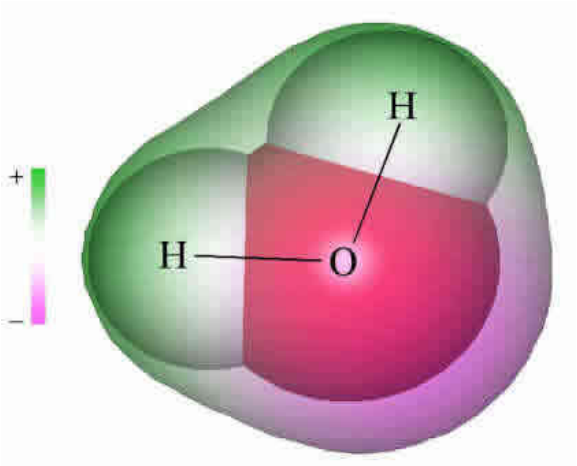


Figure 3.
Although the water molecule carries no net electric charge, its eight electrons are not distributed uniformly; there is slightly more negative charge (purple) at the oxygen end of the molecule, and a compensating positive charge (green) at the hydrogen end. The resulting *polarity* is largely responsible for water's unique properties. (3)

The polarity of the water molecule (more positive on the hydrogen “side”, more negative on the oxygen “side”) allows water molecules to be attracted to each other - opposites attract. This type of attraction is a very weak type of chemical bond referred to as hydrogen bonding and this is what produces the hexagonal symmetry as seen in Figure 4.

Ice: $H_2O(s)$

- Water has many different crystal forms; the hexagonal ice is the most common
- Hexagonal ice forms a regular lattice, and thus has a low entropy
- Hexagonal ice has lower density than liquid water; ice floats

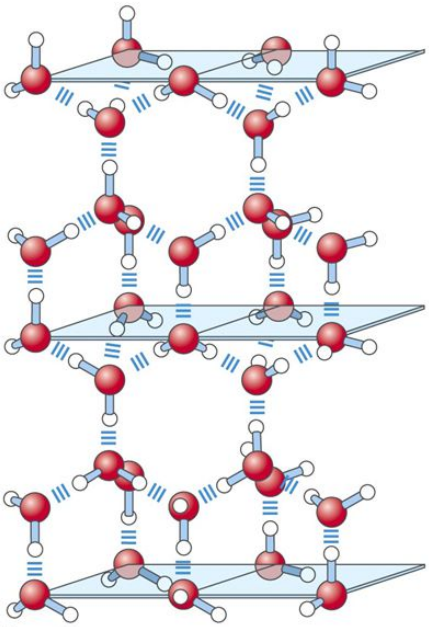
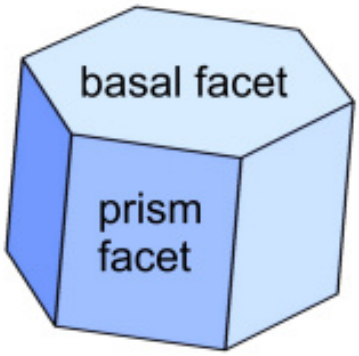


Figure 2-2
Lehninger Principles of Biochemistry, Fifth Edition

Figure 4

In the above figure the oxygen molecules are red, the hydrogen molecules are white, the covalent bonds are solid blue sticks and the hydrogen bonds are represented by three parallel lines. (4) The term low entropy means that the molecules are in a very ordered state and easy to predict (statistical thermodynamics). The arrangement seen is representative of a crystalline lattice or a regular repeated three–dimensional arrangement of molecules (or atoms or ions) in a crystalline solid (frozen water).

All snowflakes begin their “life times” as three dimensional hexagonal prisms. The hexagonal shape determined by how the water molecules “fit” into the crystalline lattice. Each prism has two basal facets and six prism facets as seen in Figure 5A. (5) Hexagonal prisms can be long, slender, hexagonal columns, or thin, flat, hexagonal plates or anything in between. (Figure 5B)



A

B

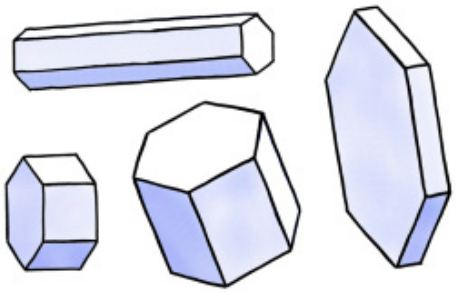


Figure 5. (5)

When examining pictures of snowflakes the hexagonal prism that was the origin of the flake can be noted. Some are subtle but many are very obvious. A few examples are shown in Figure 6.

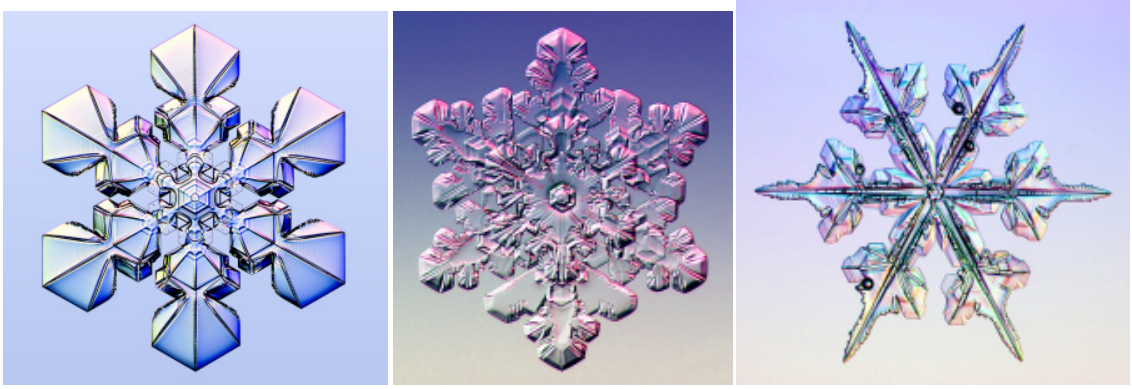
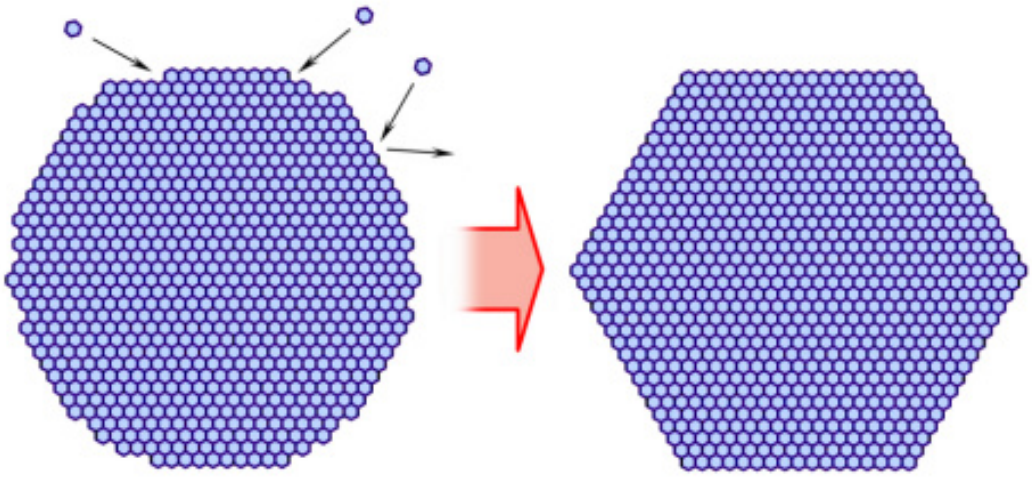


Figure 6. Photographs using colored lights to highlight the edges for better viewing. (5)

So how do snowflakes grow from the simple hexagonal plate or column (Figure 5) into the elaborate structures shown in Figure 6? There are three processes that largely determine

the complexity you see: faceting, branching and sharpening. These three processes along with the molecular shape of water give rise to *physical morphogenesis*: the spontaneous creation of pattern and form by inanimate materials, the process by which order arises from chaos. (5)

Faceting is the process that seeks order; the physical process that drives the formation of smooth surfaces. Dr. Libbrecht explains this very concisely on his SNOW CRYSTALS.com website and is reproduced below with his permission.



"Figure 7. Facets appear on snow crystals as they grow. Water molecules in the air strike the crystal surface and stick, but some stick more readily than others. The water molecules stick especially well to rough spots on the surface, where there are lots of available chemical bonds. They stick less well to smooth areas with fewer bonds. As a result, the smooth surfaces accumulate material more slowly than rough surfaces. The rough parts soon fill in, leaving just the smooth, faceted surfaces." (5)

Branching occurs because the six corners stick out further in the humid air encouraging faster growth. As more water molecules are "recruited" into the forming lattice the more side branching occurs. This is a type of *growth instability*, which contributes to a type of chaotic growth as contrasted to the faceting process. Dr. Libbrecht offers an excellent cartoon (Figure 8) to illustrate the phenomena. (5)

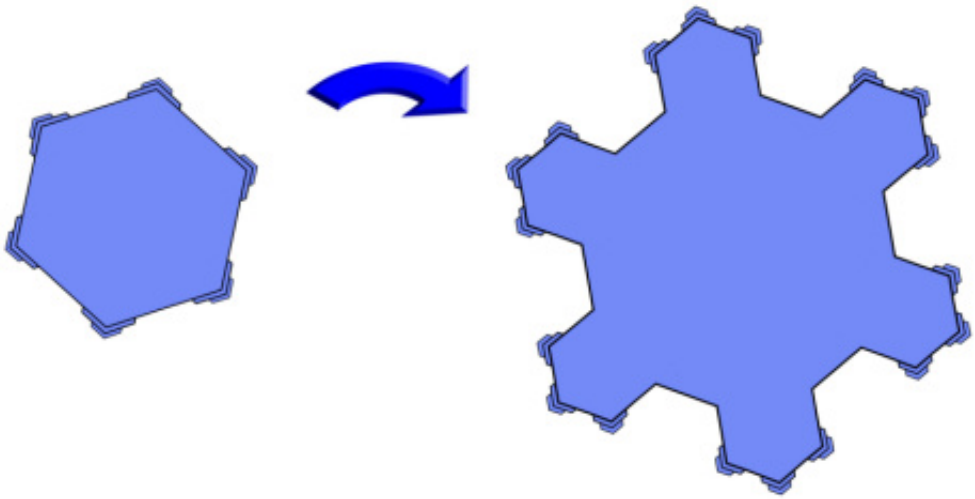


Figure 8

As the crystal grows it recruits or grabs the water molecules from the supersaturated vapor surrounding it. The closer molecules are taken in and as growth continues the distance the molecules have to travel to the crystal becomes greater. The growth of the crystal slows down. This is *diffusion limited growth* and it tends to lead to branching. Below is a figure of growing crystals showing the *zone of clearing* around it where all of the close water molecules have been grabbed out of the water droplets. Close inspection shows that the droplets closest to the crystal are smaller than the ones on the periphery. Water molecules are diffusing out of these droplets and "feeding" the crystal so it will grow. Branching is just starting on the left crystal while on the right, branching is approaching completion.

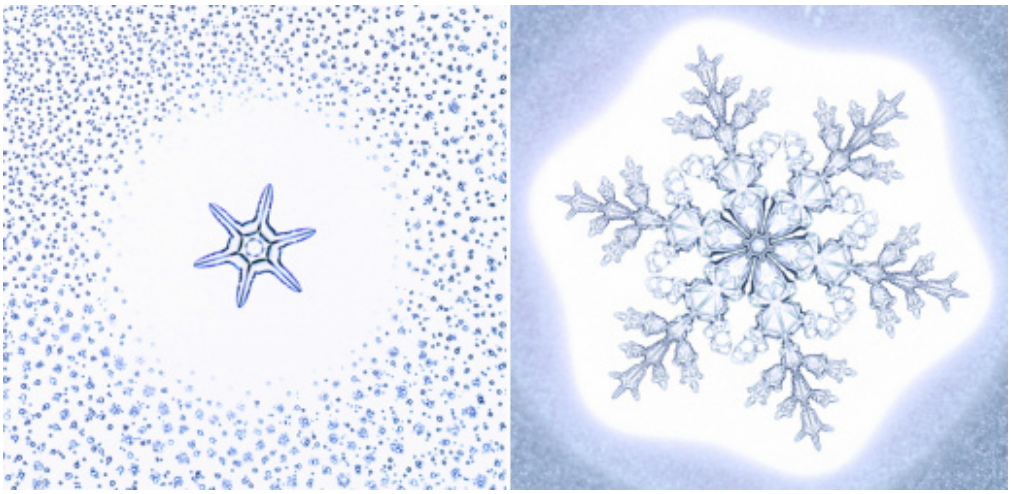


Figure 9. Snowflakes, zones of clearing and water droplets. (5)

Another unstable process that occurs at the corners is called *edge-sharpening growth instability.* "Turns out the growth of a faceted surface depends on the width of the facet. When (the) last molecular terrace is less than 100 molecules wide (roughly), it becomes especially easy for molecules to attach to the top of the terrace. Strange, but that seems to be part of how ice works. This quality tends to sharpen the crystal edges. ….. when a corner grows, it produces narrow faceted terraces. A narrow terrace grows faster than a wide terrace, and the growth then adds more terraces that are even narrower than before. The result is an edge-sharpening growth instability." (Ken Libbrecht, 5)

This interplay between order (faceting) and chaos (branching and sharpening) as water molecules freeze out of the vapor (supersaturated) phase over a fairly wide temperature range (0 to -35 ^{o} C) produces the remarkable snow flake.

But how does a snowflake begin? What starts everything? If ice is present then the flake begins to grow but if no ice is present the water will just get super cooled but not start forming the lattice. Something is needed to start things rolling, so to speak. This is referred to as the *nucleation event*. Atmospheric dust (i.e. inorganic) is the usual described nucleator but more recently studies have also shown >1% of snowflakes in an average snowfall have DNA containing material as the nucleators. This suggests bacteria, plant detritus and other biologic material are playing a roll which has implication from improving weather/precipitation forecast to explaining plant pathogen dissemination strategies. (6) Whether ice, inorganic dust or organic/DNA containing material the nucleator starts the freezing process going and the water molecules begin to add into the lattice. A snowflake is born.

There are many more aspects of snowflake science that have not been discussed in this review but there is one property of snowflakes that bridges the disciplines of philosophy, systems theory, science and art. This is the process called emergence. Emergence is defined as a process whereby larger entities, patterns and regularities arise through interactions among smaller or simpler entities that themselves do not exhibit such properties. (7) Another way of stating this is, the final snowflake pattern cannot be predicted by the antecedent conditions: water molecules, temperature, humidity and wind. In fact, what the final snowflake pattern will be cannot be predicted even when grown under very controlled laboratory conditions. (8,5)

Why this is the case can be explained partially by chemistry and mathematics. Not all hydrogen atoms are the same. In fact about one out of every 5,000 contains a neutron. A hydrogen atom containing a neutron is called deuterium and is distinguishable from ordinary hydrogen by weight, being twice as heavy. Hydrogen with one proton in the nucleus is called protium. Protium and deuterium are isotopes of hydrogen. Isotopes are two or more forms of a chemical element having the same number of protons in the nucleus, or the same atomic number, but having different numbers of neutrons in the nucleus, or different atomic weights. Oxygen, too, has isotopes. The most common form of oxygen is ^{16}O. About 1 out of every 500 atoms of oxygen contains two extra neutrons (^{18}O). Because of isotopes, each water molecule has a number of possible configurations:

1) 2 hydrogen + $1^{16}O$
2) 1 hydrogen + 1 deuterium + $1^{16}O$
3) 2 deuterium + $1^{16}O$
4) 2 hydrogen + $1^{18}O$
5) 1 hydrogen + 1 deuterium + $1^{18}O$
6) 2 deuterium + $1^{18}O$

with each having a different weight and a slightly different conformation within the lattice. (9)

"Now, a snow crystal might contain a billion billion (10^{18}) molecules (of water), give or take a few, and we see on average one in 500 of these will be different from the norm. Furthermore, these rogue atoms will be randomly scattered throughout the crystal, with many, many, many different possible configurations. Really, it is a mind-boggling number of possible configurations, more than all the protons and electrons in a million trillion universes like our own. Thus, the probability that two snow crystals would have exactly the same layout of these molecules is utterly, vanishingly small. It could snow day and night until the sun dies before two snow crystals would be exactly, precisely alike." (Ken Libbrecht, 10)

And that only describes the molecular complexity. What about the other physical (meteorological) dynamics that determine the final snowflake: wind, temperature and humidity within a snow cloud containing an undeterminable number of microenvironments? This is why the morphology diagram shown in figure 1 is still somewhat a mystery. A general morphological description can be made for the type of crystals that will form but the final pattern is beyond the ability of science to predict! Similar yes, identical no.

One other property of snowflakes is a process called molecular self-assembly. Molecular self-assembly is defined as a process by which molecules adopt a defined arrangement without guidance or management from an outside source. (11) Quoting Dr. Lebbrecht: "The snowflake is a very simple example of self-assembly. There is no blueprint or genetic code that guides the growth of a snowflake, yet marvelously complex structures appear, quite literally out of thin air." (12) Actually self-assembly, the attraction of water molecules into the lattice, is one of the factors driving physical morphogenesis. (13)

So what quality or qualities of snowflakes (crystals) could challenge the mechanistic naturalism that is somewhat pervasive but not limited to science? Mechanistic naturalism is really a philosophical term that is applied to science in an attempt to define how science works.

Mechanistic (adjective) is defined as: of or relating to theories that explain phenomena in purely physical or deterministic terms; determined by physical processes alone. In physics and mathematics deterministic allows for no randomness. This is to say that the same starting conditions will always produce the same result. The Oxford English Dictionary defines naturalism as: "idea or belief that only natural (as opposed to supernatural or spiritual) laws and forces operate in the world." In practice some scientists embrace a more specific form of naturalism referred to as methodological naturalism which has been defined

as: “the assumption that observable events in nature are explained only by natural causes, without assuming either the existence or non-existence of the supernatural, and so considers supernatural explanations for such events to be outside science. It holds that the scientific method (hypothesize, predict, test, repeat) is the only effective way to investigate reality, and that such empirical methods will only ascertain natural facts, whether supernatural facts exist or not.” (14) Mechanistic naturalism denies the supernatural while methodological naturalism claims *nolo contendere*.

In the above review snowflake formation has been explained in purely material/natural (i.e. physics, chemistry and mathematics) terms. No supernatural explanations were put forward. But the data reported that snowflakes are definitely not deterministic. But is that totally true? It depends on the scale of the observation. On the macro/gross level, given water vapor (supersaturated) and the correct meteorological conditions snowflakes are produced. Snow can even be predicted to occur with some accuracy. So with further scientific discovery, more refinement of predictive models will man’s accuracy of snow prediction reach the deterministic threshold of no randomness? Perhaps or most probably. One only has to look at the history of man’s accuracy of predicting physical phenomena like eclipses and tides to see how science takes on the task of describing physical processes in the material world.

On the micro/molecular level each snowflake appears to be unique and perhaps challenges naturalism. But once again much of this uniqueness is explicable in purely physical (i.e discoverable) terms. At the current time individual snowflake morphology is not predictable but the processes, faceting, branching, edge sharpening, etc. are becoming more explicable. This is the industry of science, the arena of the scientist. Dr. Lebbrecht eloquently states his place in this particular scientific endeavor: “The snowflake's six-fold symmetry was explained in the early 20th century, when X-ray crystallography revealed the hexagonal structure of the ice lattice, and crystal faceting was worked out in detail in the 1950s. Dendritic branching was solved (for non-facet branching) in the 1980s, and the faceted branching seen in snowflakes was first demonstrated on the computer in 2005. The edge-sharpening instability was only discovered a few years ago, and is still not well understood. The morphology diagram (Figure 1) is still an unsolved scientific puzzle.
People have been trying for centuries to figure out exactly how snowflakes work, and the job is far from finished. I am striving to add my own small contributions to a subject of scientific inquiry that has been ongoing for more than four hundred years. The snowflakes keep falling, and it seems that there are always a few of us trying to explain exactly why they look like they do.” (5)

So, the snowflake, beautiful and even mysterious for the moment to scientific discovery, may not offer a rebuttal to mechanistic naturalism. They are a phenomenon of the physical/material world. They are symmetrically pleasing but complex enough to generate interest to the human mind/brain. (15) This complexity coupled with the characteristics of uniqueness (no two are alike) and emergence is persuasive of an intelligent design explanation.

Intelligent design here is the (pseudo)scientific theory that challenges natural selection (a scientific theory) by proposing an intelligent cause that cannot be detected by science but the results can be described and noted using scientific methodology. (16) Physical phenomena such as self-assembly, emergence and complexity are some of the characteristics that are cogent support of this theory. The results noted are very complex physical structures like DNA or information within the fossil record that does not lend itself to interpretation at this point in time. Interestingly, intelligent design proponents do not seem interested in engaging physics to any degree. In description it is similar to a "God of the gaps" explanation garbed in a cloak of scientific method rhetoric while refraining from describing the intelligent cause aspect of intelligent design. Intelligent design is an example of how man attempts to reconcile the material world with the spiritual world.

But is a reconciliation even needed? Is a belief in the supernatural and the practice of science in opposition? Perhaps looking at the extremes may define a reconciliation need. On one hand there is the extreme scientist: materialistic, naturalistic, atheist who holds the supernatural believers to be self deluded, factual denialists. On the other hand is the extreme believer: fundamental (biblical, Islamic, etc), unquestioning follower who holds the scientist to be a God denying, idealogue with delusions of naturalistic causation. There are certainly notables in each of these extremes. Diametrically opposed extreme views are seldom, if ever, reconcilable for many reasons (inflexibility, hubris, ego investment, etc). Fortunately, on the whole, the majority of humanity function somewhere in between.

Since this paper was written to mount a challenge to "materialistic-mechanistic philosophy permeating modern-day scientific thinking" only the scientist will be considered for the remainder of the discussion. Methodological naturalism and having a belief in the supernatural are not mutually exclusive. And perhaps that is where the 51% of scientist place themselves, who believe in God or a supernatural power, when questioned in 2009. (17) Statistics like these have been reported since 1914 and the believers and non-believers have been consistently 50/50. Taking this into account, science in the 21st century, with its explosive growth, does not appear to be any more or less persuasive on the question of belief in the supernatural.

This belief or non-belief by scientists is a rather peculiar question. Are plumber's beliefs questioned? Stockbrokers? Mechanics? Why scientists in particular? A scientist's belief system has little, to nothing, to do with acceptance and use of their scientific data unless they step outside of science and enter the field of philosophy.

"Natural scientists (such as the biologists, chemists, and physicists that make up the Pew study (17)) are no more equipped to make conclusions about God than they are equipped to make conclusions about economics, history, literature, or philosophy. Since the question of God is philosophical in nature, scientists who investigate it are just as equipped as laymen, and their opinions should be placed on the same footing as any other educated non-scientist."(18) How society uses the information a scientist discovers is not predicated on the personal belief system of the scientist. (19)

Of course there are notables who defy the above quote; who after very successful scientific careers pursue careers as philosophers and theologians. (20-23) In fact Wikipedia has a page titled *List of Christians in science and technology* that begins in the 1100s and continues to the present. (24) There are also lists for Jews and Muslims. It is interesting to note that it is difficult to find individuals (especially in more modern times) that have successful careers in theology or philosophy and turn to practicing science as a second career. Does this observation tell us anything about scientists and their beliefs? One interpretation is that scientists are individuals who are seekers for explanations. Their interpretation of data from their seeking will guide their next endeavor just as experience influences any individual of normal mind.

So returning to the snowflake, what can be discerned? Science can be a passion that takes enormous commitment as seen in Dr. Libbrecht's study of snowflakes (pictures, movies, books, papers). Science demands rigor to give accurate description of the phenomena under investigation (hexagonal ice, faceting, branching, edge-sharpening, isotope lattice building, etc). Science requires time and the scientist of today stands on the shoulders of the scientists who have gone before (400 years of snowflake studies). Science is accelerating (snowflakes studied for over 400 years but more major advances in the last 100 years). Science moves onward, pressing the boundaries of man's ignorance of the physical world (gross observation to x-ray crystallography to computer modeling). (25)

Do snowflakes offer a convincing argument to mechanistic naturalism? Probably not. Will more investigation bring more understanding of the conundrums that snowflakes pose to the existing body of knowledge of the material world? Most probably yes. Will this knowledge prove anything about God, faith or the spiritual world? No.
Will snowflakes continue to inspire the scientist, the filmmaker, the artist and the casual observer. Absolutely. Where that inspiration leads the individual is a personal decision.

Proposal: Water may offer a better challenge to mechanistic naturalism.

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Urantia Book Quotes

81:2.9 (901.12)But the frank, honest, and fearless search for true causes gave birth to modern science: It turned astrology into astronomy, alchemy into chemistry, and magic into medicine.

12:9.3 (141.4) Mathematics, material science, is indispensable to the intelligent discussion of the material aspects of the universe, but such knowledge is not necessarily a part of the higher realization of truth or of the personal appreciation of spiritual realities. Not only in the realms of life but even in the world of physical energy, the sum of two or more things is very often something *more* than, or something *different* from, the predictable additive consequences of such unions. The entire science of mathematics, the whole domain of philosophy, the highest physics or chemistry, could not predict or know that the union of two gaseous hydrogen atoms with one gaseous oxygen atom would result in a new and qualitatively superadditive substance — liquid water. The understanding knowledge of this one physiochemical phenomenon should have prevented the development of materialistic philosophy and mechanistic cosmology.

111:4.6 (1220.5) Snow crystals are always hexagonal in form, but no two are ever alike. Children conform to types, but no two are exactly alike, even in the case of twins. Personality follows types but is always unique.

195:5.2 (2075.5) Truth often becomes confusing and even misleading when it is dismembered, segregated, isolated, and too much analyzed. Living truth teaches the truth seeker aright only when it is embraced in wholeness and as a living spiritual reality, not as a fact of material science or an inspiration of intervening art.

195:5.3 (2075.6) Religion is the revelation to man of his divine and eternal destiny. Religion is a purely personal and spiritual experience and must forever be distinguished from man's other high forms of thought, such as:
195:5.4 (2075.7) 1. Man's logical attitude toward the things of material reality.

195:6.1 (2076.6) Scientists have unintentionally precipitated mankind into a materialistic panic; they have started an unthinking run on the moral bank of the ages, but this bank of human experience has vast spiritual resources; it can stand the demands

being made upon it. Only unthinking men become panicky about the spiritual assets of the human race. When the materialistic-secular panic is over, the religion of Jesus will not be found bankrupt. The spiritual bank of the kingdom of heaven will be paying out faith, hope, and moral security to all who draw upon it “in His name.”

195:6.2 (2076.7) No matter what the apparent conflict between materialism and the teachings of Jesus may be, you can rest assured that, in the ages to come, the teachings of the Master will fully triumph. In reality, true religion cannot become involved in any controversy with science; it is in no way concerned with material things. Religion is simply indifferent to, but sympathetic with, science, while it supremely concerns itself with the *scientist.*

195:6.4 (2076.9) At the time of this writing the worst of the materialistic age is over; the day of a better understanding is already beginning to dawn. The higher minds of the scientific world are no longer wholly materialistic in their philosophy, but the rank and file of the people still lean in that direction as a result of former teachings. But this age of physical realism is only a passing episode in man’s life on earth. Modern science has left true religion — the teachings of Jesus as translated in the lives of his believers — untouched. All science has done is to destroy the childlike illusions of the misinterpretations of life.

195:6.5 (2077.1) Science is a quantitative experience, religion a qualitative experience, as regards man’s life on earth. Science deals with phenomena; religion, with origins, values, and goals. To assign *causes* as an explanation of physical phenomena is to confess ignorance of ultimates and in the end only leads the scientist straight back to the first great cause — the Universal Father of Paradise.

195:6.12 (2077.8) Science may be physical, but the mind of the truth-discerning scientist is at once supermaterial. Matter knows not truth, neither can it love mercy nor delight in spiritual realities. Moral convictions based on spiritual enlightenment and rooted in human experience are just as real and certain as mathematical deductions based on physical observations, but on another and higher level.

195:6.17 (2078.3) The sincere pursuit of goodness, beauty, and truth leads to God. And every scientific discovery demonstrates the existence of both freedom and uniformity in the universe. The discoverer was free to make the discovery. The thing discovered is real and apparently uniform, or else it could not have become known as a *thing.*

195:7.2 (2078.5) Science should do for man materially what religion does for him spiritually: extend the horizon of life and enlarge his personality. True science can

have no lasting quarrel with true religion. The “scientific method” is merely an intellectual yardstick wherewith to measure material adventures and physical achievements. But being material and wholly intellectual, it is utterly useless in the evaluation of spiritual realities and religious experiences.

195:7.9 (2079.4) A mechanistic philosophy of life and the universe cannot be scientific because science recognizes and deals only with materials and facts. Philosophy is inevitably superscientific. Man is a material fact of nature, but his *life* is a phenomenon which transcends the material levels of nature in that it exhibits the control attributes of mind and the creative qualities of spirit.

195:7.18 (2080.3) Any scientific interpretation of the material universe is valueless unless it provides due recognition for the *scientist.* No appreciation of art is genuine unless it accords recognition to the *artist.* No evaluation of morals is worth while unless it includes the *moralist.* No recognition of philosophy is edifying if it ignores the *philosopher,* and religion cannot exist without the real experience of the *religionist* who, in and through this very experience, is seeking to find God and to know him. Likewise is the universe of universes without significance apart from the I AM, the infinite God who made it and unceasingly manages it.

195:7.20 (2080.5) Science lives by the mathematics of the mind; music expresses the tempo of the emotions. Religion is the spiritual rhythm of the soul in time-space harmony with the higher and eternal melody measurements of Infinity. Religious experience is something in human life which is truly supermathematical.

195:7.22 (2080.7) The universe is not like the laws, mechanisms, and the uniformities which the scientist discovers, and which he comes to regard as science, but rather like the curious, thinking, choosing, creative, combining, and discriminating *scientist* who thus observes universe phenomena and classifies the mathematical facts inherent in the mechanistic phases of the material side of creation.

195:7.23 (2080.8) The scientist, not science, perceives the reality of an evolving and advancing universe of energy and matter.

133:5.4 (1476.6) Scientists may some day measure the energy, or force manifestations, of gravitation, light, and electricity, but these same scientists can never (scientifically) tell you what these universe phenomena *are.* Science deals with physical-energy activities; religion deals with eternal values. True philosophy grows out of the wisdom which does its best to correlate these quantitative and qualitative observations. There

always exists the danger that the purely physical scientist may become afflicted with mathematical pride and statistical egotism, not to mention spiritual blindness.

133:5.5 (1476.7) Logic is valid in the material world, and mathematics is reliable when limited in its application to physical things; but neither is to be regarded as wholly dependable or infallible when applied to life problems. Life embraces phenomena which are not wholly material. Arithmetic says that, if one man could shear a sheep in ten minutes, ten men could shear it in one minute. That is sound mathematics, but it is not true, for the ten men could not so do it; they would get in one another's way so badly that the work would be greatly delayed.

133:5.6 (1477.1) Mathematics asserts that, if one person stands for a certain unit of intellectual and moral value, ten persons would stand for ten times this value. But in dealing with human personality it would be nearer the truth to say that such a personality association is a sum equal to the square of the number of personalities concerned in the equation rather than the simple arithmetical sum. A social group of human beings in co-ordinated working harmony stands for a force far greater than the simple sum of its parts.

133:5.7 (1477.2) Quantity may be identified as a *fact,* thus becoming a scientific uniformity. Quality, being a matter of mind interpretation, represents an estimate of *values,* and must, therefore, remain an experience of the individual. When both science and religion become less dogmatic and more tolerant of criticism, philosophy will then begin to achieve *unity* in the intelligent comprehension of the universe.