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DESCARTES' OBSERVATIONS ON THE AMSTERDAM SNOWFALLS OF 4, 5, 6 AND 9 FEBRUARY 1635

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Abstract. In *Les météores* (1637), in the midst of a rather far-fetched theory of their origin, Descartes incorporated a detailed description, from actual observation, of a variety of kinds of snow crystals and hail particles. These even include the *tsuzumi* crystals, described as "wheels joined two by two by an axle" or as "little crystal columns decorated at each end with a six-petalled rose", and such exceptional forms as twelve-rayed and eight-rayed stars. The accompanying diagrams, which have been reproduced a number of times, are distinctly inferior to his verbal description.

Résumé. *Observations de Descartes sur des chutes de neige à Amsterdam, les 4, 5, 6 et 9 février 1635.* Dans *Les météores* (1637), au milieu d'une théorie assez aventurée de leur origine, Descartes incorporait une description détaillée, à partir d'une observation réelle, de plusieurs types de cristaux de neige et de grêlons. Ils comprenaient même des cristaux de type "tsuzumi" décrits comme "plusieurs autres telles rouës, jointes deux à deux par vn aissieu" ou comme "petites colomnes de cristal, dont chasque bout estoit orné d'vne rose à six feuilles", et des formes aussi exceptionnelles que des étoiles à douze rayons ou à huit rayons. Les dessins qui accompagnaient le texte ont été reproduits un grand nombre de fois, mais sont nettement inférieurs à la description par le texte.

Zusammenfassung. *Descartes Beobachtungen uber die Schneefälle in Amsterdam am 4., 5., 6. und 9. Februar 1635.* In *Les météores* (1637), mitten in einer reichlich weit hergeholten Theorie über deren Herkunft, hat Descartes eine auf wirklichen Beobachtungen beruhende, genaue Beschreibung einiger Arten von Schnee-Kristallen und Hagelkörnern aufgenommen. Dazu gehören auch die *Tsuzumi*-Kristalle, die er als "Räder, die paarweise durch eine Achse verbunden sind" oder als "kleine Kristall-Säulen, an beiden Enden mit einer sechsblättrigen Rose verziert", beschreibt, sowie so aussergewöhnliche Formen wie zwölf- und achtstrahlige Sterne. Die beigegebenen Figuren, die mehrfach reproduziert wurden, bleiben weit hinter seiner Beschreibung mit Worten zurück.

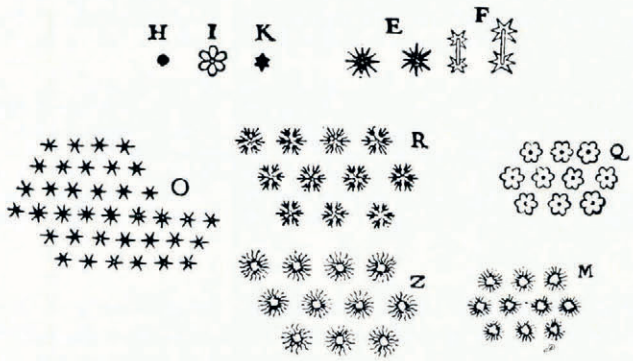
The unbridled imagination, founded on the euphoria of his discovery of the scientific method, with which René Descartes could persuade himself of his ability to explain anything, blended strangely, almost uniquely, with his capacity for exact perceptive observation. Few with the former *penchant* could avoid letting it colour their vision, by, at least selectively, seeing what they expected to see: but Descartes could switch totally from the one mood to the other in alternate sentences, and keep them separate. It is indeed interesting to observe the change of style, from lucid and lively sentences describing what he saw, to sentences ever more involved as his imagination takes him further from reality. But his accurate descriptions (Descartes, 1637) not only of the simpler snow crystals, plain and rimed, but even of *tsuzumi* crystals and twelve-rayed stars, which three hundred years later assume such importance in Nakaya's (1954) recognition of the essential three-dimensional nature of the snow crystal, deserves all admiration: it ought not to share oblivion with a discarded far-fetched theory.

In *Les météores*, published in 1637 with the *Discours de la méthode*, following a passage in which he explained that snow crystals were flat because pressed together by the wind, which somehow assembled them in planar layers, he wrote (I translate rather literally from the French*):

"And thus the exterior face of the cloud, which was previously as seen at Z or M becomes, afterwards, such as one sees at O or Q, and each of the particles of ice of which it is composed has the shape of a little rose or star, very well formed.

* The French is the original text: the Latin version published seven years later is a translation revised by the author but not written by him.

But, lest you should think I speak only by opinion, I will give you here the account of an observation I made last winter, 1635. On the 4th February, the air having previously been extremely cold, there fell in the evening at Amsterdam, where I then was, a little *verglas*, that is to say rain which froze on reaching the ground; and afterwards there followed a very fine hail, the grain of which, having about the size represented at H, I judged to be drops of the same rain, which had frozen in the upper air. However, instead of being exactly round, as doubtless the drops had been, they had one side notably flatter than the other so that they resembled in shape that part of our eye called the crystalline humour. From which I knew that the wind, which was then very strong and very cold, had had the power to change the shape of the drops while freezing them. But what astonished me most was that among the grains which fell last I noticed some which had around them six little teeth, like clock-makers' wheels, such as you see at I. And these teeth being very white, like sugar, whereas the grains which were of transparent ice, appeared nearly black, appeared manifestly to be made of a very subtle snow which had attached itself around them after their formation, as white hoar-frost attaches itself around plants. And I knew this the more clearly from the fact that at the finish I came across one or two which had around them countless little hairs, composed of a paler and more subtle snow than that of the little teeth around the others, such that it



could be compared with them as the uncrushed ash which covers burning charcoal with the ash which has been reheated and piled up in the grate. I only had difficulty to imagine what could have formed and made so exactly symmetrical these six teeth around each grain in the midst of free air and during the agitation of a very strong wind, until I finally considered that this wind had easily been able to carry some of these grains to the bottom or to the top of some cloud, and hold them there, because they were rather small; and that there they were obliged to arrange themselves in such a way that each was surrounded by six others in the same plane, following the ordinary order of nature. And moreover, as it is very likely that the heat, which must have been present a little earlier in the upper air, to cause the rain which I had observed, had also generated there some vapours which this same wind had driven against these grains, where they had frozen in the form of very delicate little hairs, and had even perhaps helped to hold them up: so that they would have more easily remained suspended, until they were again subjected to some heat. And that, this heat first melting all the hairs around each grain, except those finding themselves face to face against one of the six other grains surrounding it, because their coldness would have impeded its action, the substance of these melted hairs had immediately mingled itself among the six aggregates of those remaining, and having by this means strengthened them and rendered them to some extent less penetrable to heat, they had frozen together and thus had made these six teeth. Whereas the numberless hairs which I had seen around some of the last grains to fall had not been

reached by this heat. On the morning of the following day, at eight o'clock, I observed again another sort of hail, or rather of snow, of which I had never heard tell. These were little plates of ice, very flat, very polished, very transparent, about the thickness of a sheet of rather thick paper, and of the size shown at K, but so perfectly formed in hexagons, and of which the six sides were so straight, and the six angles so equal, that it is impossible for men to make anything so exact. I saw at once that these plates must have been at first little pellets* of ice, arranged as I have just described, and pressed by a very strong wind, accompanied by enough heat, so that this heat had melted all their hairs, and had so filled their pores with the moisture from them that from white, which they had been before, they had become transparent; and that this wind had at the same time so strongly pressed them one against the other that no space had been left between a pair of them, and that it had also flattened their surfaces in passing above and below and had thus precisely given them the shape of these plates. There only remained a little difficulty, in that, these pellets of ice having been half melted and at the same time pressed one against the other, they had not stuck together but had remained separate; for, taking express care to look for it, I could never find two adhering to each other. But I soon satisfied myself on the point by considering the way in which the wind continually agitates and deforms the surface of water, without making it rough and unequal. For I knew from that infallibly it deforms and undulates in the same way the surfaces of clouds and that in continually moving each particle of ice a little differently from its neighbours it does not allow them to stick together completely, though it does not disarrange them on that account, and that it does not cease however from flattening and polishing their little surfaces: in the same way as we sometimes see that it polishes those of the waves it makes in the dust of a field. After this storm-cloud, there came another, which produced only little roses or wheels with six rounded semicircular teeth, as shown at Q, and which were quite transparent and quite flat, of about the same thickness as the plates preceding them, and formed as perfectly and symmetrically as one could possibly imagine. I even perceived, at the centre of some of them, a very small white spot which one could have said was the mark of the point of the compass which had been used to round them. But it was easy for me to judge that they had been formed in the same way as the plates, except that, the wind having pressed much less, and the heat having been perhaps a little less, their points had not been completely melted but only a little shortened and rounded at the ends into the shape of teeth. And for the white point which appeared at the centre of some of them, I did not doubt that it resulted from the fact that the heat which changed them from white to transparent had been so mild that it did not completely penetrate to their centre. There followed, after this, a further quantity of such wheels joined two by two by an axle,† or rather, since at the beginning these axles were quite thick, one could as well have described them as little crystal columns decorated at each end with a six-petalled rose a little larger than their base. But after that there fell more delicate ones, and often the roses or stars at their ends were unequal. But then there fell shorter and progressively shorter ones till finally these stars completely joined, and fell as double stars with twelve points or rays, rather long and perfectly symmetrical, in some all equal, in others alternately unequal, as shown at F and E. And all this gave me occasion to consider that the particles of ice in two different planes or layers placed one above the other in the clouds could more easily join together than those in a single layer. For, while the wind,

* "Peloton" translated here and later as "pellet", can mean "ball" or "platoon". As it is here used to signify an aggregate of six grains around one in a particular configuration, the word "group" (or even "platoon" in view of the quasi-military arrays of snow crystals shown in figures M, O, Q, R and Z) would arguably make better sense: but I think "pellet" is the intended meaning, if it is to be the same at every use of the word.

† Descartes has not been well served by the engraver of his figures whose representation of the *tsuzumi* crystals at F shows a misunderstanding of this accurate verbal description. Likewise, the figure fails to indicate the oval character, mentioned below, of the six eight-rayed crystals in O. In French, the phrases describing the *tsuzumi* are "plusieurs autres telles rouës, jointes deux a deux par vn aissieu" and "petites colomnes de cristal, dont chasque bout estoit orné d'vne rose a six feuilles".

acting as a rule more strongly on the lower of these layers than on the upper, makes them move a little quicker, as already remarked, nevertheless it can sometimes act on them with equal force and make them undulate alike: principally when there are only two or three of them above each other, and when, sieving itself between the pellets which comprise them, it causes those of these pellets which correspond in different layers to remain immobile relative to each other, in spite of the agitation and undulation of these layers, because in this way it has the easiest passage. At the same time the heat, being no less prevented by the proximity of the pellets of two different layers from melting their contiguous hairs, than by the proximity of those in one layer, melts only the other hairs around which, mixing with those which remain, and freezing again, makes the axles or columns which join these little pellets, at the same time as they change themselves into roses or stars. And I was not surprised by the thickness of the columns which I had noticed at the beginning, although I well knew that the material of the little hairs which had been around the two pellets could not suffice to compose them: for I thought that there had been perhaps four or five layers one above the other, and that the heat, having acted more strongly on the two or three in the middle, than on the first and the last, because they were less exposed to the wind, had almost entirely melted the pellets composing them, and from them had formed these columns. I was not surprised, either, to see often two stars of unequal size joined together; for, taking note of the fact that the rays of the larger one were always longer and more pointed than those of the other, I judged that the cause was that the heat, having been stronger around the small one than the other, had to a greater extent melted and blunted its points; or indeed that the smaller one could also have been composed of a smaller ice-pellet. Finally, I was not surprised by the double stars with twelve rays which fell later; for I judged that each had been made from two simple six-rayed stars by the heat which, being stronger between the two layers than outside, had completely melted the little threads of ice which joined them, and thus had stuck them together; as also it had shortened those joining the others which I had seen fall immediately before. Now, among some thousands of these little stars which I examined that day, paying express attention to the point, I could never find any with more or less than six rays, except a very small number of doubles, which had twelve, and four or five others which had eight. And these were not exactly round, like all the others, but somewhat oval, as seen near O; from which I judged that they were formed by the conjunction of the extremities of two layers, which the wind had pushed one against the other at the same time as the heat converted their little pellets into stars. For they had exactly the shape which that should produce, and this conjunction, made exactly in a straight line, could not be hindered so much by the undulation caused by the wind, as that between the particles of a single layer; besides which the heat can also be greater between the edges of these layers, when they approach each other, than elsewhere; and this heat having partially melted the particles of ice which are there, the cold which follows at the moment when they begin to touch, can easily stick them together. For the rest, besides the stars of which I have spoken up to now, which were transparent, there fell an infinity of others that day, which were quite white like sugar, and of which some had almost the same shape as the transparent ones; but most had their rays more pointed and more delicate, and often divided, sometimes in three branches, of which the two at the sides were bent outwards on either side, and the central one remained straight, so that they looked like fleur de lis, as one sees at R; and sometimes in several, giving the appearance of feathers, or fern leaves, or the like. And there also fell, among these stars, a quantity of other particles of ice in the form of threads, and without other determinate shape. All the causes of which are easy to understand; for, as for the whiteness of these stars, it was only due to the fact that the heat had not fully penetrated their interiors, as was shown by the fact that all those which were very thin were transparent. And if sometimes the rays of the white were no less short and blunt than those of the transparent ones, it was not that they had been melted as much by the heat, but that they had been pressed more by the winds; and commonly they were

longer and more pointed, because they had been less melted. And when these rays were divided in several branches, it was that the heat had left the little hairs composing them as soon as they had begun to approach each other in assembling themselves. And when they were only divided in three branches it was that the heat had left them a little later; and the two side-branches bent outwards on either side when this heat withdrew, because the proximity of the central branch immediately rendered them colder and less flexible on its side, which formed each ray into a fleur de lis. And the ice particles of no definite shape assured me that the storm clouds were not all composed of little knots or pellets, but that there were some of them only made of randomly mixed threads. As for what caused these stars to descend, the violence of the wind which continued all that day made it very clear to me; for I judged that it could easily disarrange and break up the layers which they composed, after having made them; and that, as soon as they were thus disarranged, leaning one of their edges towards the earth, they could easily split the air, because they were quite flat, and heavy enough to descend. But if sometimes such stars fall in calm weather, it is that the lower air, in contracting draws all the clouds towards itself, or that the air above, in expanding, pushes the cloud down, and disarranges them in the same way: whence comes it that in this case they are usually followed by more snow, which did not happen on that day. The following morning, there fell flocks of snow, which seemed to be composed of an infinite number of little stars joined together; however, inspecting them more closely, I found that those in the interior were less regularly shaped than those at the surface, and that they could easily result from the dissolution of a cloud like that marked G above [in a figure not reproduced here]. Then, this snow having stopped, a sudden stormy wind brought a little white hail, very long and fine, of which each grain had the form of a sugar-loaf; and the air becoming clear and serene soon after, I judged that this hail was formed in the highest part of the clouds, of which the snow was very subtle and composed of very delicate threads, as I have just described. Finally, three days later, seeing a fall of snow all composed of little knots or pellets surrounded by many intermixed hairs and without any stellar shape, I confirmed myself in the credence of all that I had imagined touching this matter."

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