many of them possess one qualification for success which most men lack: they have, at all events, time at their disposal.

Do not let me be misunderstood. I am far from desiring that the students of Bedford College should leave its walls impressed only with the importance of adding to knowledge, and inclined to neglect other and, at least as urgent duties. In my opinion, no man or woman can afford to cultivate any one part of their nature to the exclusion of the others. Sad stories have sometimes been told of homes in which work has been done which will never be forgotten, but done at the cost of all the brightness and happiness which are usually associated with the name of home. This want of the sense of proportion, of the relative importance of different claims, casts a shadow on the brightest intellectual fame. I am not asking for such sacrifices. I believe that in general they are absolutely unnecessary. But where the over-mastering curiosity of the born investigator exists, it will find a career, which may indeed involve self-sacrifice, but which need make no harsh demand on others.

There are, to my knowledge, at the present moment a large class of men who are living more hardly than they otherwise might live, who are cheerfully surrendering days which might be given to pleasure or to money-making, and are spending laborious nights, simply because they are impelled by the desire to add something to the pile of knowledge which our race is through the centuries accumulating. It cannot but be that if the same spirit animated the women and girls of this generation, many would be found among them who, without neglecting any duty, would work with the same energy for the same object.

It is possible that some of my hearers may accuse me of holding up an impossible ideal. My answer is that the founders of Bedford College held up to their generation an ideal which was then regarded as impossible but which has nevertheless been realised. Women, if they please, can now be educated to the same high level as men. I in turn venture to hold up to you an ideal at which Bedford College should aim in the future. It is that it should be known as a place of learning as well as a place of education, as a place where not only is the number of those who know added to, but where knowledge itself is increased.

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## *THE INNER STRUCTURE OF SNOW CRYSTALS.*

THE ice and snow crystals photographed and described by me[1] may be referred to the following types.

I. Crystals developed in the direction of the vertical axis. (*a*) Hexagonal prisms. (*b*) Bottle-shaped prisms. (*c*) Needles.

II. Tabular crystals. (*a*) Hexagonal tables. (*b*) Stellated tables. (*c*) Dendritic tables.

III. Crystals equally developed along the vertical and lateral axes.

Among these groups, types I. (*c*) and III. are in no way different from the ordinary hexagonal crystals, and accordingly of less general interest. The former, I. (*c*), is common in drifting snow; to the latter belong the sharp edged hexagonal prisms *without cavities*, which compose the under layers of the snow covering. They are never found among the snowflakes, and are accordingly originated by a molecular change in the snow covering. Type II. (*c*) comprises the relatively large dendritic crystals with complicated ramifications which are visible even to the naked eye as handsome regular stars. They have been figured and described by several observers, from Claus Magnus and Keppler to Scoresby and Glaisher, and I shall therefore not dwell upon them in the present paper. Of the remaining extremely interesting types (I. *a*, *b*; II. *a*, *b*), which, owing to their microscopic dimensions, have hitherto received no attention from men of science, I give a brief description.

### I. (*a*) *Hexagonal Prisms.*

Fig. 1 shows the commonest type. It is bounded by the basal planes and the hexagonal prism, and of interest on account of the *hour-glass shaped cavities* invariably present within the crystal. These are, as shown by the figure, widest near the two basal planes, where they are bounded by a negative hexagonal prism; nearer the centre they contract again to expand in the form of two bulbs, elongated to points and confluent. The shape of the cavities is almost always the same. Crystals of this type are very small (about 0·5 mm. long), and the inner structure only distinguishable under the microscope. They are common in drifting snow.

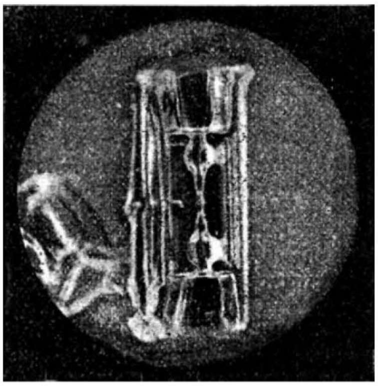

Fig. 1.

### I. (*b*) *Bottle-shaped Prisms.*

The bottle-shaped crystals of elongated prismatic form have the appearance shown in Fig. 2. Like the crystals of the preceding type, they are bounded by an hexagonal prism and the basal plane; but one end is pointed, and the crystals accordingly hemimorphic. The bottle-shaped crystals also contain cavities, less regular, however, than those in the crystals of the preceding type. The following circumstance attaches a special interest to these crystals. On February 8 there was a rather sparse fall of agglomerations of bottle-shaped crystals such as are shown in Fig. 2. *The cavities in these crystals proved under the microscope to*

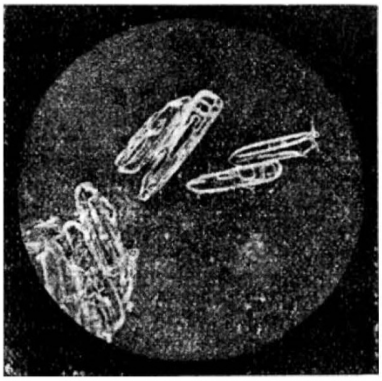

Fig 2.

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[1] "Geol. Foren. i Stockh." Forh. Bd. 15, p. 146.

*contain water in which one could sometimes* (as in Fig. 2) *discern a small air-bubble.* On the day when this snowfall occurred the temperature was − 8° C. Still there was a continual dripping of water from the house roofs, in spite of the fact that the sky was overcast, and the sun thus could not contribute to melt the snow. The dripping continued even at midnight in a temperature of − 12° C. Shortly after the fall of snow a transformation could be observed in the crystals; on the surface of the snow they had passed from prismatic bottles to hexagonal tables *without any cavities.* The above described fall of small ice-bottles containing water, a phenomenon, as far as I know, new to meteorologists, combined with the transformation of the crystals after their descent, affords a simple explanation of the fact that, in spite of the severe cold, the new-fallen snow was so saturated with water as to cause an incessant dripping from the roof.

### II. (*a*) *Hexagonal Tables.*

To the naked eye these crystals look like small, lustrous scales. Their dimensions vary between 0·8 and 1·4 mm. Under the microscope they prove to contain regular cavities, remarkable as being bounded not by planes, but, contrary to the accepted principles of crystallography, by *regularly distributed curved surfaces.* The limits of these cavities are shown under the microscope as fine black markings, to which, on account of their resemblance to forms within the organic world, I have applied the name of *organoid* lines, cavities, and formations. The following example will illustrate the structure of such crystals, including such organoid cavities. The snow-crystal (Fig. 3) shows in the centre a handsome star. The crystal is composed of two (or more?) superimposed tables, with the same orientation. The different hexagons indicate the outer limits of these tables. Two tables are united by a stratum, which has the outlines shown by the stellate figure. Within this figure the crystal is therefore homogeneous; without the same, its two different layers are separated by a flattened cavity, bounded by sinuate surfaces, and probably containing air. The same star includes some extremely regular cavities of smaller size. On this table we can observe a hemihedral development, the six triangular fields into which the hexagon is divided by lines drawn between the centre, and the angles being only alternately equal to each other. Such a hemihedry is the rule in this type. It is most developed in some almost triangular tables that occur among the equilateral hexagons. The above described structure, two tables united by a stellate layer of ice, is the general rule in the tabular ice crystals.

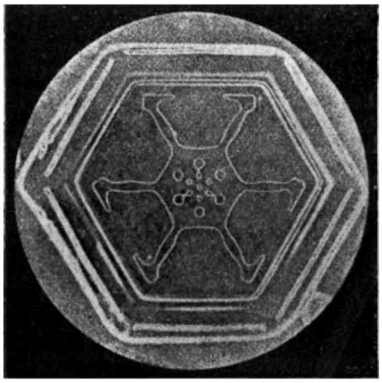

FIG. 3.

The organoid figures show a great multiplicity of forms, but the fundamental type is the same in all of them. It is evident that their outlines are fixed by certain crystallographic laws yet unknown to us. We might possibly find in these organoid formations, which so strongly remind us of shapes in the world of life, a clue to the mathematical laws of the structural outlines of organisms. Or perhaps these remarkable organoid figures are caused by microscopical aërozoic organisms, around which the crystals have developed. I hope next winter to be able to collect observations for the answering of this question

### II. (*b*) *Stellate Tables.*

Figs. 4-6 show some of the countless modifications exhibited by crystals of this type. The central table often shows beautiful organoid figures sometimes hemihedrally developed and regularly orientated cavities. Similar cavities, usually of very minute size, are with great regularity distributed in the arms of the star.

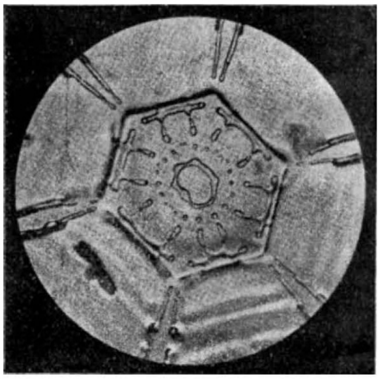

FIG. 4.

The ramification of the plates has some connection or other with the orientated cavities. Through each arm of the six-sided star runs what may be called the *main nerve,* which originates either in the central plate or just outside it. This nerve is present in all the tables and dendritic stars with elongated arms. The main nerve is bounded by two fine, parallel *gas canals.*

The first beginning of these canals consists of two or four small cavities with parallel orientation. In the continuation of these small cavities lie larger ones, often prolongated to extended canals (see Fig. 4). Owing to evaporation on the surface of the crystal, these canals gradually become open, first at one end, and then along a part or the whole of their extent, only the ridge that divides them remaining as a *nerve* (Fig. 5). That these canals are really cavities in the ice I have ascertained by observing and photographing snow crystals in a coloured liquid,

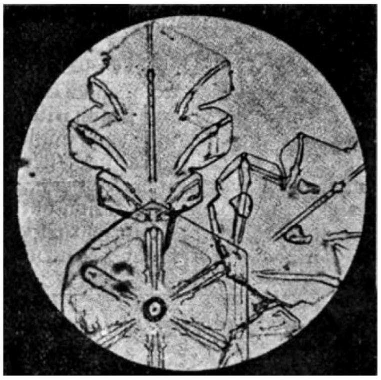

FIG. 5.

I found that the liquid gradually penetrated into and filled the canals which were open. Fig. 4 shows the central parts of crystals with canals partly filled with the coloured liquid. Near the centre small air-bubbles are still visible. Fig. 6 is the central part of a star powerfully magnified. The interesting structure may be judged by the photograph.

*Phenomena attending the Compression of Snow Crystals.*—A stellate plate was slowly compressed by screwing down the objective upon the cover-glass. After this pressure it was still entire. In the interior of the crystal *new curvilinear figures or pressure lines had appeared*, following a regular course analogous to that of the organoid figures. This analogy suggests that the latter may possibly be explained as tensional phenomena.

*Exceptional Symmetrical Conditions.*—The fine cavities in the centre of the stars are sometimes regularly arranged after only *two* symmetrical planes at right angles to each other and of different value (see Fig. 4), in accordance with the symmetrical conditions that we find in crystals belonging to the orthorhombic system.

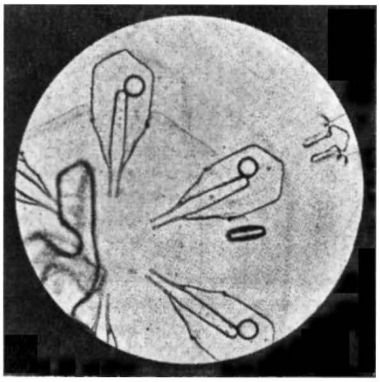

Fig. 6.

*Hoar-frost.*—In addition to the photographing of snow crystals, I have also examined and reproduced by photography crystals of hoar-frost deposited on window-panes. Even these crystals formed often hexagonal tables, but were entirely without the remarkable cavities observed in snowflakes.

The investigations of which I have here given a brief account show that the structure of snow crystals is very complicated, and display several peculiarities which, so far as we know at present, are unexampled in other crystals. I hope to be able to resume these investigations next winter on a more extensive scale, in order to obtain, if possible, a complete elucidation of the interesting phenomena alluded to in the present paper.

G. Nordenskiöld.

## *BÜTSCHLI'S ARTIFICIAL AMŒBÆ.*[1]

PROF. BÜTSCHLI, of Heidelberg, so well known by his valuable work on the Protozoa, and his contributions to Bronn's "Klassen und Ordnungen," has, in the monograph under review, approached a subject of deep interest and great difficulty, namely, the cause of protoplasmic movement. His researches in this direction are already known to readers of the *Quarterly Journal of Microscopical Science*, for in 1890 Prof. Lankester inserted a letter from Prof. Bütschli, in which the latter gave a short account of his experiments. In the present monograph his researches are given in a completed form and in great detail. The gist of the whole subject may be put as follows:—Prof. Bütschli makes an artificial oil and water emulsion in a way suggested by Nuincke, and finds that under certain conditions drops of this emulsion exhibit streaming movements and changes of shape: according to Prof. Bütschli, protoplasm is itself a natural emulsion, and the streaming and amœboid movements of protoplasm are, like those of the artificial emulsion, due to surface tension.

Working at emulsions, Nuincke had previously found that if substances soluble in water be finely powdered and rubbed up with oil, and the oil subsequently surrounded with water, the latter diffuses into the oil, which it converts into a foam or emulsion of little water droplets closely packed together in the oily matrix. The emulsion may obviously be compared with the sea-foam, in which we find air globules closely packed in a water matrix, the oil in the emulsion and the water in the sea-foam having an alveolar or honeycomb build or form. The Nuincke emulsion is obviously, too, the reverse of the emulsions made by Johannes Gad with weak $K_2CO_3$ and oil, in which the oil droplets lie closely packed in a water matrix; it is also the reverse of the numerous emulsions made every day by the druggist who uses oil in mucilage, malt-extract, &c. When Bütschli first tried the Nuincke method he used common salt, sugar, and nitre, taking these as examples of substances readily soluble in water. He succeeded, however, better by using $Na_2CO_3$, or $K_2CO_3$, and proceeded as follows. The salt, preferably $K_2CO_3$, was obtained pure and dry, and was finely powdered in an agate mortar. He then breathed upon it until it was slightly moist, and rubbed it up with olive oil until a thick white paste was formed. A tiny drop of the paste was then placed on the centre of a cover-glass, and inverted over a drop of water, and in order that the drop might not be pressed out of shape by the weight of the cover, the latter was supported by little pellets of wax or paraffin. The preparations so obtained were placed on one side in a damp chamber for twenty-four hours, and then washed out with water by inserting a piece of blotting-paper into the chink between the slide and cover, and supplying fresh water at the opposite side of the cover by means of a pipette. The water was then replaced by equal parts of glycerine and water, after which the drops of emulsion became clear and transparent, exhibiting changes in shape and streaming movements very much like those of an amœba. It appears that the consistency of the olive oil is a very important factor in determining the successful issue of one of these experiments. Ordinary oil is of no use, it must be kept for some time in an open vessel, though the time may be shortened by keeping it in a hot-air chamber at 50°C. and testing the oil from day to day. It must be thick and viscous, but not too much so.

When examined by the aid of a microscope the emulsion appears as a network of oil enclosing the water droplets, for the structure is, of course, seen in optical section. Curious streaming movements may be observed within the emulsion, and these may continue for hours; movements of the drop as a whole occur, and always in the direction of the stream. If the emulsion drop be carefully watched it will be seen to change its shape, and to throw out processes—which, by the way, are always club-shaped—and to withdraw others. Up the centre of these processes a streaming movement takes place, and the streams at the tops of the processes spread out and flow back in a layer next the surface. These movements are influenced by warmth and electricity, and we have, therefore, in these Bütschli's drops something which might deceive one into supposing that actual amœbæ were in the field of observation.

The movements of the oil emulsion are due, no doubt, to changes in the surface tension of the fluids in contact with each other, Bütschli's case being an illustration of

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[1] "Untersuchungen über mikroskopische Schäume und das Protoplasma." Von O. Bütschli. (Leipzig: Wilhelm Engelmann, 1892.)