still. Missolonghi is on the northern shore of the bay; to reach Patras, the steamer crosses to the Peloponnesus side, and here we leave the Ionian Sea.

There is now a railroad from Patras to Athens. On the morning when we made the transit there was given to us for our sole use a saloon on wheels, which was much larger than the compartments of an English railway carriage, and smaller than an American parlor car. In its centre was a long table, and a cushioned bench ran round its four sides; broad windows gave us a wide view of the landscape as we rolled (rather slowly) along. The track follows the gulf all the way, and we passed through miles of vineyards. *But I did not think of currants* here; they had been left behind at Zante. There is, indeed, only one thing to think of, and the heart beats quickly as Parnassus lifts its head above the other snow-clad summits. We ought to have been crossing the gulf in a Phæacian boat, which needs no pilot, or, at the very least, in a bark with an azure prow. But even upon an iron track through utilitarian currant fields, the spell descends again when the second peak becomes visible at the eastern end of the bay.

"Not here, O Apollo,
Are haunts meet for thee,
But where Helicon breaks down
In cliff to the sea—"

How many times, in lands far from here, had I read these lines for their mere beauty, without hope of more!

And now before my eyes was Helicon itself.

ICE AND ICE-MAKING.

BY T. MITCHELL PRUDDEN.

IF one were to ask his friends what mineral we are most familiar with and most commonly used as food, the answers would probably be both varied and amusing. Salt would, I fancy, first suggest itself to many, and to those whose training in physiology and hygiene has not been neglected, no doubt the claims of lime and iron and carbon, which, in one form or another, we use with food to build up bone and brawn, would be amply urged. But, after all, it is water, for water is a mineral—a fused mineral. You will find it described as such, along with quartz and topaz and the diamond, in Dana's *Mineralogy*, or in other treatises on stones.

We usually think of minerals as solid things, such as metals and rocks and jewels and various chemical salts. But when we consider the matter a little we see that all these things if melted by strong heat are minerals still, only they are now in a fluid instead of in a solid state. The difference between these minerals and water is that water gets fluid at a lower temperature than they do, and, like quicksilver, stays melted at ordinary living heat. But in those old ice ages which, one after another, have swept now over the Northern and now over the Southern hemisphere, bringing ruin and desolation, the natural and common condition of water was that of a solid—ice—as it largely is to-day out-of-doors in winter when not kept fused by the stored-up heat of the soil and rocks, or melted by the sun.

Everybody knows that water can exist as a solid (ice), as a liquid, and as a gas (steam).

The remarkable differences in appearance which water presents when in these different conditions depend simply upon the amount of heat which it contains. But what is heat?

Every well-informed person knows nowadays that heat is not a material thing as it was once supposed to be, which could be stored away in one substance and forced out of another, or which could be conjured into being here and annihilated there at the will of man. Heat is a kind of motion of the ultimate particles of which matter is composed. It is one of the ways in which what the physicists call energy manifests itself. Water, like all other substances, is made up of exceedingly small ultimate structures called molecules. And when these molecules of water are left to themselves, they tend to become grouped in certain definite ways to form a solid mass which we call ice. This is their natural resting state. When the molecules are exposed to the kind of motion or undulation which we call heat, they lose their fixed and definite relation to one another, and become mobile or vibrant, and then we have the fluid—water. Increase this molecular motion by exposing them to further heat, and they shun one another in a frenzy of vibration, and this is steam. The curious thing about it is that the steam can only become water again, and the water ice, by giving up this heat to something else—that is, when the molecules can set a-swinging the molecules of some other thing.

If you put a lump of ice into a kettle of cold water and put it over a flame, the ice will gradually melt, but the temperature of the water will not rise above that of melting ice until all is fluid. A large amount of heat *seems* to have been lost. The force which this vanished heat represents seems to have been annihilated. It has not been lost, however, but has been simply transferred to the molecules which were still in the ice, but are now, in consequence of the heat transfer, swinging back and forth in the fluid water.

Heat the water still further, and the temperature will rise until it reaches the boiling-point—100° centigrade or 212° Fahrenheit—and there it stays until the whole of the water has been converted into steam. Make the fire as furious as you like, not one degree hotter does the water get. The heat here too seems to be lost. It is not; but, as before, is converted into molecular motion—a motion so intense that the molecules of the water fly apart, and thus make of the water a gas—steam. This heat, which disappears in melting the ice and in converting the water into steam, is called the *latent heat* of water and steam respectively, which means simply that it is being temporarily employed in inducing moderate or intense molecular motion.

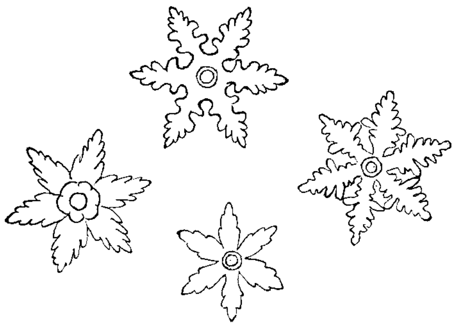
We are told, and can intellectually grasp the fact, that the heat which makes our earth inhabitable, and directly or indirectly supplies nearly all the varied forms of power which are used in the world's work, comes from the sun. Of the heat which is poured down upon the earth in the daytime a large portion is stored temporarily in the rocks and soil and water; much is used up in the evaporation of the water to form the atmospheric moisture and the clouds; much is consumed in the building up of the bodies of animals and plants. But all the time the supra-atmospheric spaces claim a large share of the stored-up heat.

Heat is of an unrestful nature, and is readily communicated from one body to another by contact or by radiation.

We rarely realize, I think, how easily the earth parts with this heat, and how cold space is through which the earth sweeps in its orbit. Nor do we commonly appreciate how relentlessly space sucks away the heat which the earth has garnered from the sunbeams, out into its illimitable depths. 'Way out in space is a cold so intense that we fairly fail to grasp its meaning. Perhaps 300 or 400 degrees below the freezing-point of water, some philosophers think, are the dark recesses beyond our atmosphere. And night and day, summer and winter, this insatiate space is robbing us of our heat, and fighting with demoniac power to reduce our globe to its own bitter chill. So, after all, our summer and winter temperatures are only maintained by the residue of the sun's heat which we have been able to store up and keep hold of in spite of the pitiless demands of space. Our margin sometimes gets so reduced on nights in winter that we can readily believe the astronomers and physicists when they tell us that a reduction of the sun's heat by seven per cent. and a slight increase in the number of winter days would suffice to bring again to our hemisphere a new Age of Ice, with its inevitable desolation. The balance is really a nice one between the heat we daily gather from the sun and the share of it which we lose in space.

This is most comprehensible on cold winter nights. The genial sunbeams have struck the earth aslant, and but for a few hours, so that the soil and rocks and atmosphere have gathered during the day but little store to last over the long night; and from every exposed surface on the earth out rushes the garnered heat of the day into this more than freezing void. You can fairly feel it tugging at your face and hands.

Water out-of-doors in winter feels it too, and little by little grows colder and colder. The clashing of its molecules against each other, which is all that has made it a fluid, becomes less and less vigorous. Their mutual attractions, which have been antagonized and held in check by the furious commotion which the sun's heat had wrought, come slowly into play, until finally the molecules rush together in those groups and masses which we call crystals, and for the first time perhaps in months or years sink into rest. The symphonies of motion in the water which the heat had conjured into being as it struck molecule upon molecule fade softly into a simple harmony of form at the bidding of insatiate space. A pellicle of crystal ice, once formed over the surface of



ICE STARS.

the water, transmits out into the cold space the heat from the water below, which so, film by film, grows stark.

Most fluids shrink as they lose their heat, but water, curiously enough, just as it becomes solid in freezing, expands about $\frac{1}{11}$ of its volume, and thus becomes, bulk for bulk, lighter than water. And that is why ice forms a protecting cover to our streams and lakes and ponds; that is why icebergs swim so much above the surface instead of sinking in the sea; and that is why the mineral ice floats in the fused mineral, water, tinkling against the glass beside you as you dine. That, too, is why water-pipes burst in winter, and why those hoarse, uncanny boomings greet us in the night-time from freezing lakes and ponds.

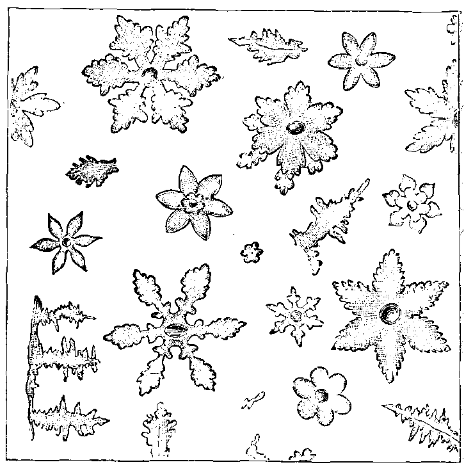
We have seen that when water loses a certain amount of its heat it becomes solid. But something more than that occurs; it becomes crystallized. Ice is not like glass, simply a transparent solid, although to the eye it looks much the same. Certain substances, and among them water, when they pass from the liquid to the solid state, assume regular geometrical forms, and these are crystals. The diamond is crystallized carbon. Quartz is a crystallized compound of silicon and oxygen, just as ice is a crystallized compound of hydrogen and oxygen.

The physicists explain crystallization by saying that the molecules of certain substances possess mutual attractions, in virtue of which, when not held in abeyance by external forces, such as heat, they arrange themselves in fixed and definite relationship to one another. These relationships of the molecules are revealed in crystals by the geometrical forms which they assume.

Although these forms of crystals vary endlessly, they are all readily grouped in a very few simple systems. Some are simple cubes or modifications of this form; some are six-sided prisms, like the common rock-crystal, and like ice. The crystals may be very minute, or they may be very large; their sides may be broad or narrow; but the angles which their sides or faces form with one another are fixed and invariable. Crystals can grow, too, by the deposit of new material over the surfaces of the old.

When crystals or masses of crystallized minerals are broken apart, they tend to separate along certain definite planes, determined by the crystalline form, and called *planes of cleavage.*

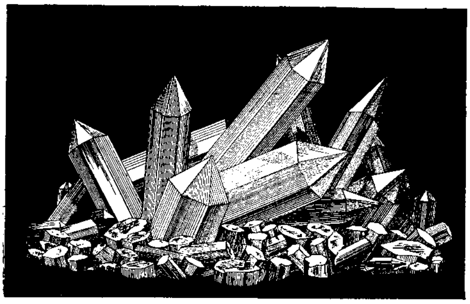
Common rock-crystals or quartz crystals, such as spectacle lenses are some-



ICE FLOWERS.

times made of, represent a crystalline group called, from their form, hexagonal prisms.

But we do not usually see the crystalline forms when we look at a lump of clear ice. It looks quite homogeneous and structureless, like glass, save that here and there bubbles of air may be



ROCK-CRYSTALS.

seen, which were caught and imprisoned when the water froze. The frost fronds on the window-panes in winter are frozen water, and although the crystals are very small and complex, they afford most readily seen examples of ice crystals.

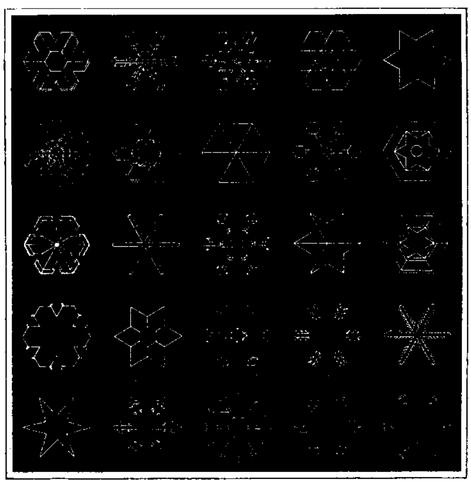
The hoary coating seen on grass and twigs and fences on frosty autumn mornings, if looked at with a lens, will be found made up of tiny ice crystals, built out of the atmospheric moisture into forms so varied and fantastic as to defy description, and so delicate that at the lightest touch of an incautious breath they fade into dewdrops.

Snow-flakes are ice crystals formed of the frozen atmospheric moisture, and grouped in varied complex stellate forms of the rarest beauty. They may easily be observed when the snow is falling through still air if one catches them on a dark cloth, such as the coat sleeve. Varied and complex as are the forms which these six-rayed crystal snow-flake stars present, the angles which their rays form with one another are invariable, and if measured, will be found to be always sixty degrees, and every subsidiary ray makes precisely the same angle with the primary ray from which it shoots.

But what about solid ice? Where are the crystals here? Tyndall has shown us how we may reveal the crystalline structure of solid ice by passing a beam of sunlight through it. The heat which these beams carry with them into the solid ice liquefy it here and there in their track, and the liquid pools which are formed, if examined with a lens, will be found to have stellate and branching forms similar to and not less beautiful than the snow-flakes and the fronds upon the frosted window-pane. They are not indeed crystals, but "negatives" of the crystals flashing out at the dainty touch of the sunbeam in the forms in which they were laid together as the molecules of the water are released from their invisible bonds.

When ice commences to form out-of-doors in winter, the first crystals shoot out horizontally over the surfaces of the water in delicate pointed spiculæ. These soon grow larger, and often stretch away in long, graceful, fernlike sweeps, or dart out from twigs and bits of grass in stellate masses. Finally coalescing at their sides as they advance, they form a roughened solid film covered all over in low relief with a bold and ever-varied tracery of most enchanting beauty. But now the direction of crystallization changes, and the water freezes directly downward, losing its surface markings as the sun now and then strikes and melts the top. Black ice at first it is—that is, ice so clear that it permits free vision into the depths where, as through a water-telescope, one stilly observant may see the water denizens at their work or play. But presently air bubbles are caught here and there through the ice mass, and it so becomes whiter and less transparent.

There is another curious and significant thing about the formation of crystals, and that is that the molecules, as they group themselves at the behest of their mysterious mutual attractions, are very intolerant of any foreign material which may be dissolved or suspended in the fluids out of which they are separating themselves in an order fixed as fate.



SNOW CRYSTALS.

This tendency is well marked and important in the freezing of water, for as the ice crystals slowly form and crowd so closely together as to make a structureless transparent mass, foreign substances, such as dust and sticks, or even smaller things than these, like the pigment particles which make ink black, or even materials wholly in solution, may be rejected by the forming crystals. Thus one may find clear ice formed on a mud-puddle, colorless ice spiculæ in an ink-bottle, and comparatively fresh-water ice at the frozen borders of the sea. Even the air, which is held in invisible solution in considerable quantity in ordinary water, is forced out of it in bubbles as it crystallizes, and may be seen in streaks and layers in almost all natural ice.

On the top of natural ice blocks as they come to us in the market one usually sees a white layer, sometimes inconspicuous, sometimes occupying a considerable proportion of the thickness of the block. This is called *snow ice*, because it is usually formed by water soaking into the snow, which so often covers the ice in winter, and there freezing. This makes a solid mass, but it is thickly crowded with the little bubbles of air which were entangled among the snow-flakes as they lay together, and were caught by the water as it froze. These it is which make the so-called snow ice look white.

But aside from the snow layer on top, natural ice often presents layers or streaks of bubbles scattered through the block from top to bottom. These air bubbles are probably in part air which has risen from the bottom of the lake or pond or stream on which the ice was forming, and been caught beneath as the water was freezing downward. They are, however, largely bubbles of air which was in solution in the water, but which has been forced out by the purifying action of the act of freezing just described.

Ice which forms on some specially favored water may, however, be almost wholly without the snow covering, and almost bubbleless.

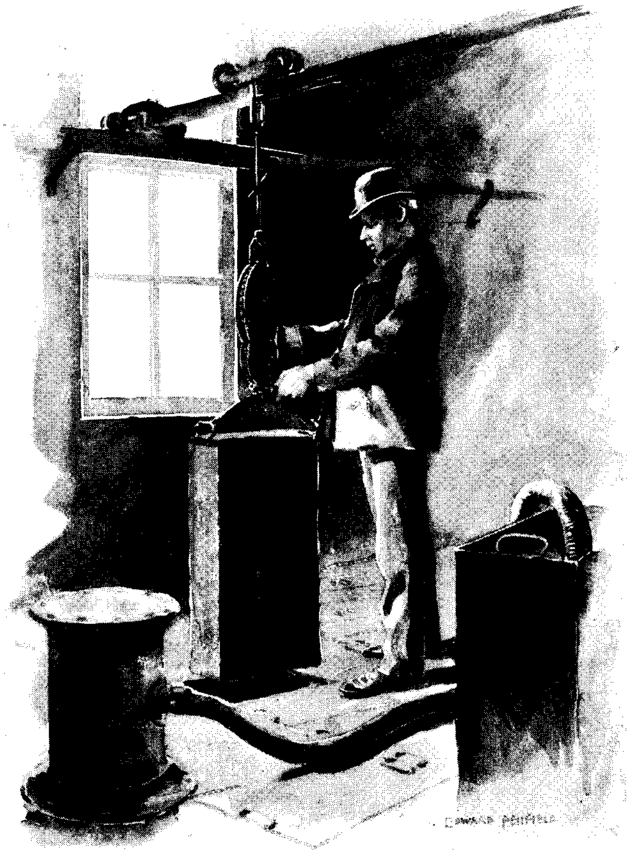
It is often interesting and sometimes profitable to stand apart a little from the rushing current of events, and trace the steps by which from time to time man has been led to hitch the forces of nature into new harnesses, and make them serve his needs and whims. The needs are often petty, the whims short-lived, as whims are wont to be, and the end achieved, looked at as a spectacle, is often wofully devoid of impressiveness when set in fancy beside the grand results which Nature furnishes when she wields her forces untrammelled. These natural forces have lost their demoniac possession in these later years, and familiarity has bred indifference to if not contempt for those servants which do our bidding at the touch of a button, and change from lions to lambs at the twirling of a valve. But they still are faithful slaves in the service of the utilities.

The chief reasons which have led to the making of artificial ice in regions where the natural product can be gathered or be brought without too great expense are twofold—first, the desirability of having this important industry freed from the uncertain vicissitudes of the weather; second, the rapidly increasing pollution by sewage of many of the waters from which ice is cut for household use, and the growing conviction that serious disease may be incurred from the use of sewage-polluted ice.

The principle on which the manufacture of ice is based is exemplified in what has already been said about the relation of heat to the conversion of water into a gas-steam. A certain amount of heat is required for the conversion of any fluid into a gas. This heat becomes, as we say, latent—that is, is being employed for the time in producing violent undulations of the gas molecules.

Whenever a liquid is converted into a gas, heat must come from somewhere. In the making of steam, it comes from the fire; in the ordinary evaporation of water out-of-doors, it comes from the sun. When there is no special heating arrangement, but the conditions are favorable for the gaseous change in the fluid, heat will be taken up from surrounding substances if they have any. If you dip your hand in water, and then wave it through the air, the water will evaporate—that is, be converted into gas—and you will appreciate by the cool sensation that heat has been abstracted from your hand. If you use instead of water some fluid which more readily passes into the gaseous state, such as alcohol or ether, the sensation of coolness will be more immediate and intense.

Now this is the principle which is applied in the manufacture of ice. Some fluid which evaporates readily is forced to do so under such conditions that the heat which it must have and render latent in its vapor will be extracted from a limited quantity of water, and this process being made continuous, so much heat will finally be abstracted from the water that its molecules can no longer stay mobile, but fly together into crystals—the water freezes.



METHOD OF EXTRACTING THE CANS OF ARTIFICIAL ICE.

The evaporating fluid used in practice may be sulphuric ether or sulphurous acid or ammonia. The last is perhaps nowadays most often used. These fluids are kept in strong close pipes and receivers, and can under no conditions come into contact with the water to be frozen.

Suppose we consider the ammonia freezing machines very briefly only, for into the details of the process it is not necessary for us here to enter.

But in order to understand this operation one more physical principle must be stated, which is that the degree of pressure to which a substance is exposed has a great influence upon the temperature at which it passes from the fluid to the gaseous condition. Water at the ordinary altitudes boils—that is, is converted into vapor—at 100° centigrade (212° Fahrenheit). But on a high mountain it will boil at a lower temperature than this, because the atmospheric pressure is less there.

On the other hand, if you put a gas into a receiver, and expose it to a sufficiently heavy pressure by a powerful pump, or in some other way, it will in most cases become a fluid forthwith, and the heat which had been latent in it will be given out. Now this in a general way is what is done to the ammonia in getting it ready to freeze water. Pure liquid ammonia boils —that is, passes from the liquid into the gaseous state—at a temperature about 240° Fahrenheit lower than water does. Hence ammonia is a substance which at ordinary temperatures is a gas. That which we buy at the drug stores as ammonia is simply a solution of the gas in water, and from this, as every one knows, it is readily given off. It is volatile, that is, it tends under ordinary conditions to get into the gaseous form. Now in ice factories powerful engines are used to force the ammonia gas by pressure into the liquid state, and the heat which is thus set free is carried off by cool water pouring over the coils of stout iron pipe in which it is confined. This fluid ammonia —kept fluid by the pressure to which it is subjected, a pressure varying from 125 to 175 pounds to the square inch—is carried in pipes to coils in the freezing-tanks. These tanks are simply great vats filled with brine, and covered over with a floor. Into this brine, cans filled with the water to be frozen are placed and carefully covered. These cans are usually between three and four feet deep, about one foot thick, and nearly two feet wide. Coils of pipe communicating with the ammonia pipes are immersed in the brine, which is kept in motion by paddle-wheels moved by machinery.

The brine acts as a carrier of the heat from the water in its tight metallic cans to the ammonia pipes. Brine is used because it does not as readily freeze as water does, and acts as a good conductor or distributer of the heat.

Now, when all is ready, the fluid ammonia under its great pressure is allowed to escape into the coils of pipe which pass about in the brine, and in which the pressure is so much less that the ammonia as it rushes in becomes at once a gas. But to do this it *must* have heat. *It must have it.* From the walls of the pipes into which it rushes, it seizes it first. These take it from the brine which bathes them until its temperature goes down, down, and it begins to draw through their iron walls upon the heat stock of the water in the cans. And so the mimic but relentless warfare goes on. The ammonia vapor is constantly pumped away from the cold pipes in which it had expanded to be used over again, while fresh liquid ammonia is as constantly forced in from behind.

Some hours pass, and the heat stock in the water is growing scantier and scantier. It can stand it in this way but little longer; it is down wellnigh to zero centigrade, and the wild insatiable vapor raging for heat in the pipes not far off is still sucking it away. The only thing which can be done now to furnish more is for the water to give up its latent heat, and that is to sign its own death-warrant as water; for, if one may use such a turn of phrase, without its latent heat water is ice.

Well, at last there is nothing for it, and that happens which is happening this clear winter night on which I write at the edge of every lake and pool and pond out-of-doors hereabouts—little transparent spiculæ shoot out from the cooled surfaces, and the water slowly, as if unwilling, yields itself into its crystal bonds.

The ice layers on all sides slowly thicken, and at last, in about sixty hours, all is solid. The watchful attendant raises with a crane the great beautiful ice block, still in its galvanized iron can, out of its cold bath, and trundles it off to make way for another molecular battle and another victory.

Water turns into ice out-of-doors in winter because it must give up the heat which it had slowly gathered from the sunbeams, at the demands of gelid space, as if an ice age in little and in brief had come again. But it is the sun's heat itself, lain dormant in the coal for ages, which, under man's directing finger and for his weal, sets free the molecular furies raging to suck from the water its motion and its simulate life.

When water freezes out-of-doors on still pools or on streams, the ice-forming does not usually go on steadily and without interruption. Warm currents in the water, sweeping under the thickening films, now and again undo the work which has been accomplished. In clear winter weather, and especially on clear winter nights, the freezing goes on best, because then space claims more eagerly its dole of heat. On cloudy nights freezing is not so rapid, since even so light and airy a blanket as a cloud keeps in the earth's heat in large measure. For the same reason a newspaper spread over a plant will often protect it from the early frosts. Snow on the ice makes, too, a blanket which retards ice-formation underneath. Warm days come when the top melts a little—and so altogether the formation of ice out-of-doors in winter in these latitudes is an irregular one, and the crystal-building is subject to many and varied vicissitudes.

Not so the artificial winter which man calls into being in his little separate iron-walled pools. Here the cooling and the freezing go steadily and relentlessly on, as regularly as the stroke of the piston in the great engines, for every one of whose throbs a myriad aqueous molecules sink into rest.

The result of this uniformity in the freezing and the regular shapes of the cans is that the artificial ice presents some interesting features in its crystalline structure to which we shall now devote some little attention.

As clearness and transparency are desirable qualities in ice designed for household use, a good deal of care and expense is requisite to free the water which is to

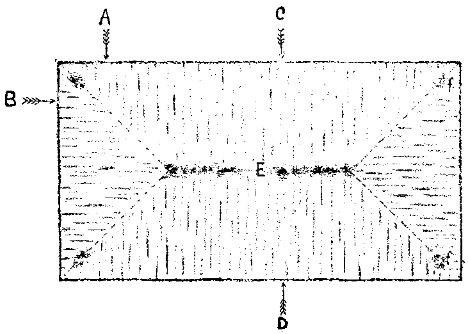


FIG. 1.—DIAGRAM OF A CROSS-SECTION OF AN ARTIFICIAL ICE BLOCK, SHOWING THE DIRECTION TAKEN BY FORMING ICE CRYSTALS.

be frozen as much as possible from the air which it holds in solution before the freezing begins. If this were not done, the ice crystals would force it out in bubbles, which, caught here and there between them, would impair the clearness of the product. Although boiling will in large measure free water of the dissolved air, this is not as efficient as distillation, which is now commonly practised, not only for the purpose of removing air, but for the destruction and removal of any bacteria or other impurities which might be in the water.

The cans being filled with distilled water and covered, and the freezing begun, it will be found, if one watches the process, that the ice crystals shoot out at right angles to the cooling surfaces, that is, to the sides and bottom of the can. Just as in natural freezing, they form, except at first, at right angles to the surface of the water. But now a very curious thing is to be noticed in the can-freezing, which is, that as the can has four sides and a bottom, the ice crystals cannot grow out into the water very far without running afoul of other crystals which have grown out from adjacent sides at right angles to those from which they sprang. How this is may be seen in Fig. 1. Crystals shooting into the water from the surfaces A and B will soon meet at right angles, and their formation be interfered with, disturbed, and stopped along a line which runs from the corner to the line of the centre. Crystals forming from the surfaces C and D will go on inwards until they meet at the central line of the ice block, E.

Now the fact is that even distilled water does, in the manipulation to which it is subjected in getting distributed into the freezing-cans, absorb a certain amount of air and certain other gases due to the decomposition by heat of organic matter in the water, and this air and these gases are necessarily forced out again by the forming crystals. The points where this squeezed-out air shows itself in tiny bubbles is just where the ice crystals finally meet end to end, that is, most abundantly along the central meeting line, E, and along diagonals running from this line to the corners of the can, f, f, Fig. 1.

Great skill is required in freezing ice in the cans, and when the most perfect result is obtained, these lines of collision of the ice crystals are almost wholly invisible. But ordinarily one may see a whitish layer of small bubbles running lengthwise through the middle of the block. Frequently one sees, too, faint lines of bubbles just within each corner

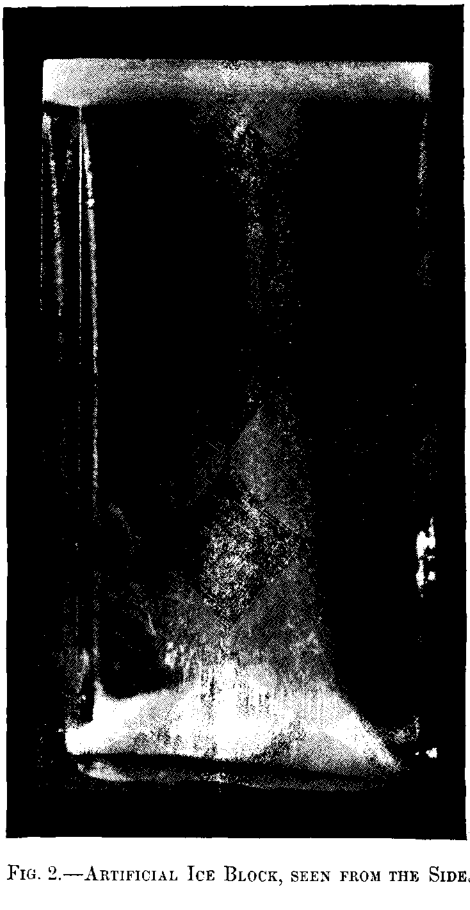


FIG. 2.—ARTIFICIAL ICE BLOCK, SEEN FROM THE SIDE.

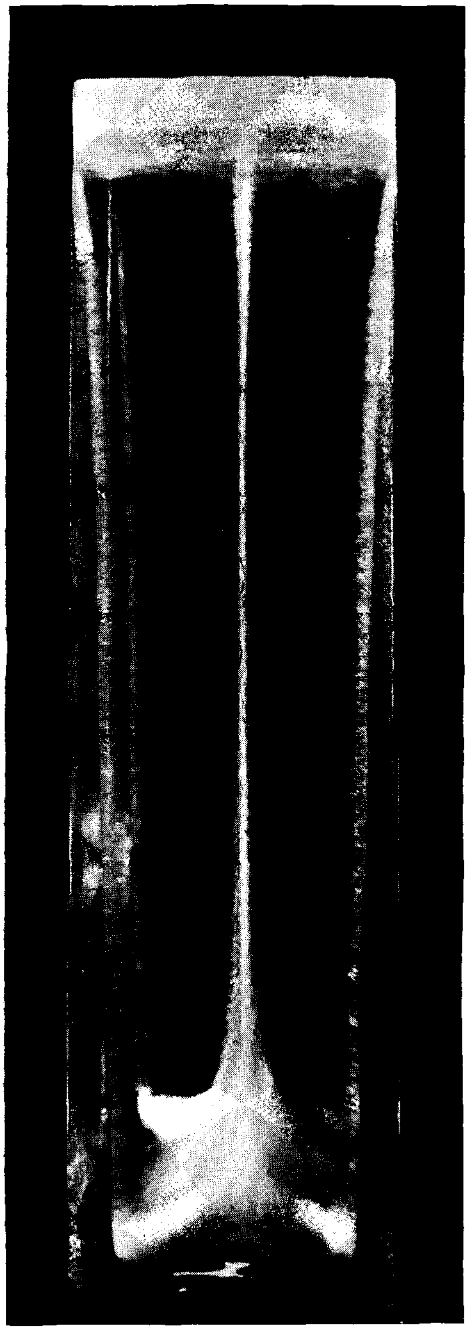


FIG. 3.—ARTIFICIAL ICE BLOCK, SEEN FROM THE SIDE.

where the crystals meet. These may be seen in Fig. 2.*

* For these photographs of artificial ice I am indebted to Dr. Edward Leaming, whose well-known skill has been freely placed at my service in this most difficult phase of sun-painting.

The block is shown standing as it is frozen in the can, and in addition to the features which I have mentioned, one sees that at the bottom of the block a considerable number of squeezed-out bubbles have been caught on the points of the ice crystals, and form a wedge-shaped mass.

If one thinks for a moment of the condition of affairs as the ice is forming, the reason for this bottom bubble wedge will be plain. Here the ice crystals bearing the bubbles at their tips are coming not only inward from the four sides of the can, but also upward from the bottom. These five different sets of ice crystals meet in planes which correspond to the four-sided peaked roof of a square or oblong house, and here the bubbles are caught, making the wedge-shaped mass. It is said by expert manufacturers that this bottom bubbly mass may be avoided by distributing the cooled brine so that the freezing may not be too rapid at the bottom.

On the top of the block the conditions are different, the cooling brine does not cover the iron can, so that when the ice has formed at the sides and well up through the water, the very top layers are frozen by the cold ice below and in thin laminæ. We thus have the general structure of an artificial ice block outlined in bands and streaks of tiny air bubbles, which are caught in certain places as the crystals form and meet. How thin the central band of bubbles is may be seen in Fig. 3, where the block is looked at from the edge.

If you peep into an ice wagon which is distributing the artificial ice through our streets, you will find the ice blocks always standing top end up as they were formed, because if the top end, which bulges from the expanding as the water freezes, were down, the blocks would wobble, and perhaps fall over.

But the story of the crystals in an artificial ice cake cannot always be made out by simple inspection when the telltale air bubbles are not imprisoned in considerable numbers. We have, however, at command in the sunbeams a magician of such delicacy and power that at his lightest touch the primal forces which have held the molecules in leash yield their sceptre, and along cleavage lines and planes of the most exquisite delicacy and beauty the ice melts, and a whole block of ice may be seen riven into prisms as sharp and distinct and delicate as any rock-crystal.

More than this, along every cleavage plane one may see with a lens the footprints of the sunbeams in bands of frond-like structures changing every instant, and at last flowing together as each crystal prism becomes separated from its neighbor by a sheet of water almost as delicate as the film of a bubble.

It is a very interesting and beautiful experiment to put a piece of artificial ice in a large pan, and setting it in the sun, watch its silent disintegration step by step. Much of interest and beauty can be seen with the unaided eye, but a hand magnifying-glass will reveal new and unexpected pictures.

One does well, in watching this experiment, to remember that under his very eyes Nature is working one of her most fascinating miracles. Here are the molecules of the ice fast locked in that rest which is crystallization, and clinging together with all the tenacity of their primal attractions. But at your will this placid state is invaded by the dancing sunbeams. By that vibratile witchery akin to music, but so hard to understand, they enter and permeate every recess of this crystal stillness. But the dance of the sunbeams in this austere domain is not for long a solitary sport. The dormant instinct of motion in the ice molecules soon awakes at the touch of this new Circe, heat, all-powerful dancing daughter of the sun, and one by one they spring into motion, and join the silent music which underlies all movements of the sea, all flow of streams, all pictures in the clouds. Of all this elemental music, the ear hears no strain. But the eye soon catches its record in faint and exquisite shining lines which flash out here and there, weaving in and out through the crystal mass, fine as a spider's thread, and stretching in long, graceful, and often interlacing sweeps, everywhere through the ice from its surfaces to its utmost depths.

As these lines grow slowly larger and more abundant, one can see that they are not scattered at random in the ice, but range inward from the surface of the block, sloping towards one another as they go, until they are lost in a mazy network at the centre of the block or along certain curious lines of junction which run inward from its corners. They are first formed along the lines and planes where the crystal masses join.

It is not easy to picture these early lines of sun-disintegration of artificial ice, owing to their extreme delicacy and fineness. But Dr. Leaming has photographed a corner of a little slab shaved out from near the bottom of an artificial ice block which had been exposed to the sunbeams for about an hour on a winter day. See Fig. 4. The direction of freezing is well shown here by the cleavage lines which the sunbeams have called forth. One sees also how along the line from the corners to the wedge of bubbles the crystals have met, and so squeezed one another in their struggle for room that they have been a little bent away from their line of contact and run in curves.

Fig. 5 is a photograph of another piece of ice cut across about the middle, showing the whole thickness of the block, and sun-dissected a little longer than the last. This is tilted a bit to show the outside surface of the ice block, and here we see the ice crystals not from their sides, but

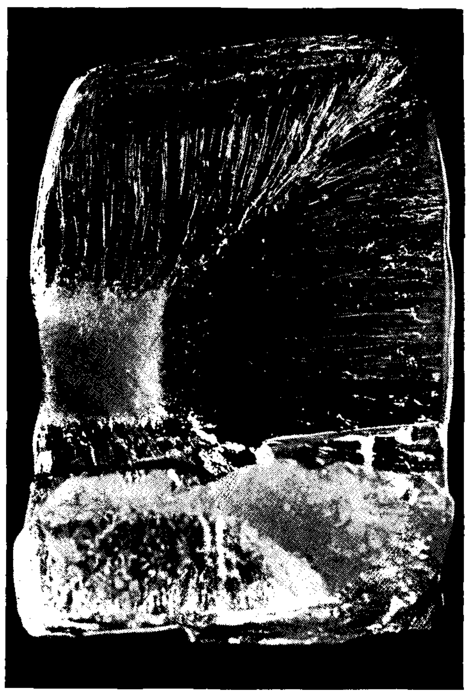


FIG. 4.—CORNER OF AN ARTIFICIAL ICE BLOCK, SUN-DISSECTED FOR AN HOUR.

from their ends; and one can see that they are, in a general way, hexagonal, like quartz crystals.

In Fig. 6 a stronger lens was used in the camera, which was focussed directly on to the ends of the crystals on the surface of the disintegrating ice block. The black spots at the angles of the rough hexagonal prisms are the ends of the lines of melting, which flash out in the clear ice at the first touch of the sunbeams, and grow steadily larger. The lines which join these tiny pools are the ends of the cleavage planes, and are covered with melting frost fronds of marvellous beauty. The lighter portions between are the bases of the ice crystals, now standing as sharply apart as the basaltic columns of the Giant's Causeway.

The melting still goes on, the channels and sluiceways grow steadily larger, and the water trickles out of them, leaving them here and there filled with air, and shining like tubes of quicksilver.

If at this time one pours over the outside ends of these sun-carven wandering channels through the ice some bright-colored fluid, such as red ink, it will run easily into them, giving an effect of red tracery in crystal, which for delicacy and brilliancy is almost unequalled by any fancy of nature or effort of art. A slice from an ice block well advanced in the sun-disintegration is shown in Fig. 7.

Thus the sunbeams of to-day pull to pieces the dainty structure which, under man's guiding finger through coal and steam and pliant gas, the sunbeams of other ages have built up.

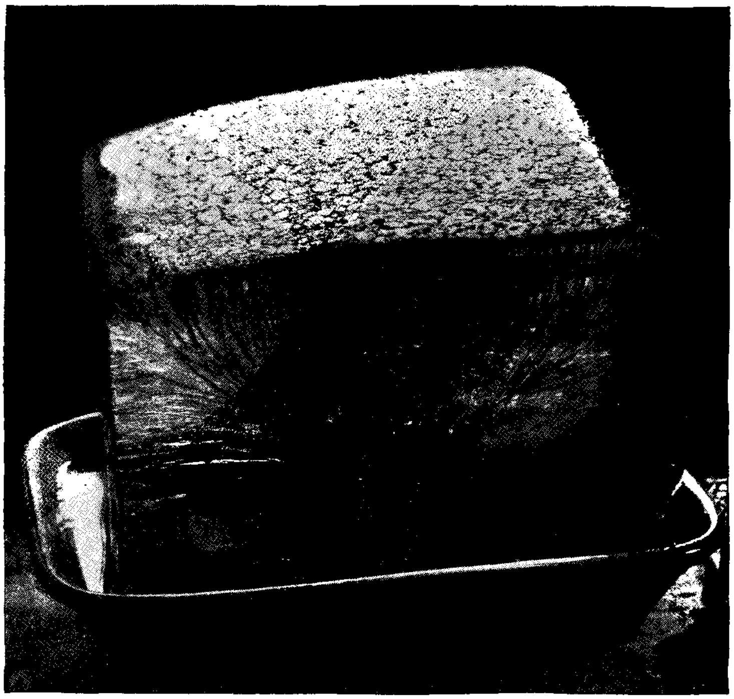


FIG. 5.—ARTIFICIAL ICE BLOCK, SUN-DISSECTED FOR AN HOUR AND A QUARTER.

Nothing could well seem more incongruous than the expression "ice flora." And yet modern science has shown us that beyond the realm of the visible is a *race of tiny plants so minute that they* may cling unheeded among the ice crystals, exclusive as these are to nearly all foreign particles, both large and small. So hardy, too, are some of these invisible plants that neither the squeezing nor the freezing which they suffer in their crystal prison-house can extinguish their life spark. But when the ice melts and they find their chosen food and warmth, they may go swarming on in their various ways, as active for man's weal or woe as before they became ice-bound.

A good many of the bacteria which are found in all natural surface waters are expelled or killed when the water freezes, but as many as ten per cent., and often more, may remain alive. A large number of studies on this subject have shown that the bubbly and snow ice is apt to contain many more bacteria than the clear ice does. These bacteria in ice have, as a rule, no influence whatsoever upon the health of the ice-consumer, if the ice has been formed on bodies of water which are clear and pure. But ice which is formed on sewage-polluted or otherwise filthy water may contain disease-producing bacteria, and hence be very dangerous for domestic use.

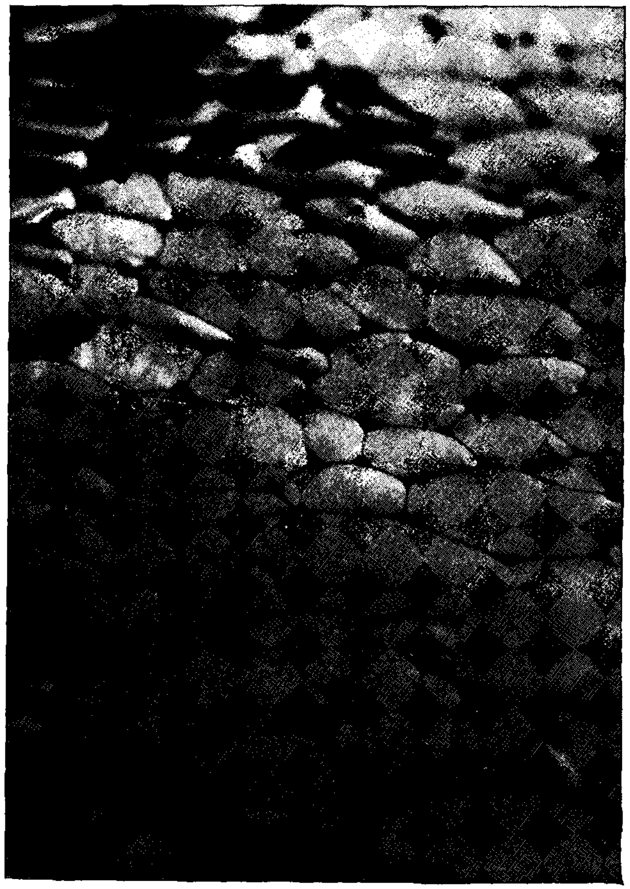


Fig. 6.—Surface of a Sun-dissected Artificial Ice Block, showing Cleavage Lines and Prisms.

It has thus come to be firmly established as a primary principle in sanitary science that sewage-polluted water should not be used for domestic purposes, either in its natural state or in its condition as ice. No water which is unfit to drink as water is fit to use for a similar purpose as ice. Its coldness may benumb the sense of taste, so that no warning of its nature comes to the consumer. Its intrinsic clearness and beauty may put him off his guard, but all ice cut from sewage-polluted waters is dangerous, and should by law be kept from the domestic market.

Ice manufactured from distilled water should, it would seem, be germ free. In fact, however, it is extremely difficult to prepare absolutely germ-free water on the large scale, and almost impossible to keep it so if once prepared, because every exposure to the air, or contact with utensils in common use, brings to it varying and often large numbers of germs which can live and grow in the water. But these small numbers of common bacteria are not of the slightest importance to the salubrity of the water.

Every one should understand that of all the myriads of bacteria about us in earth and air and water, the great majority are harmless. With very few exceptions, the bacteria which can do us harm are those, and those alone, which come from the bodies of men and animals afflicted with disease. So far as water is concerned—and the same applies to ice—it is only sewage pollution or stagnant filth which we have to fear and shun. Good, pure, uncontaminated water, and ice made from such water either by nature or by man, are entirely wholesome, and they are not made more wholesome by distillation or other purifying procedure—they are not more wholesome when germ free.

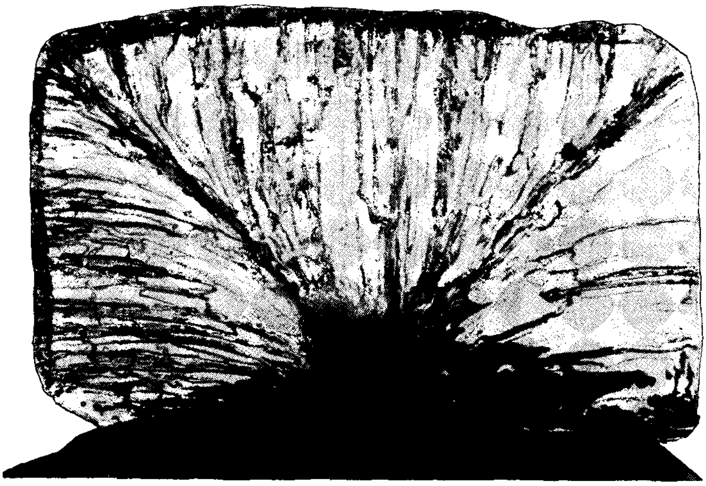


FIG. 7.—SLAB FROM AN ARTIFICIAL ICE BLOCK, ON THE POINT OF FALLING TO PIECES FROM SUN-DISINTEGRATION.

So in the manufacture of ice, if the water which is used be contaminated and impure, the preliminary distillation is of primary importance for the salubrity of the ice; but if the water be pure, the distillation is only valuable for the technical purpose of removing the dissolved air.

In point of fact, most of the artificial ice which the writer has examined—and there have been many and abundant samples from various sources collected, and for a period of many months—do contain bacteria in varying numbers. The preliminary distillation, if carefully done, destroys any disease-producing germ forms which might be present in the water used. But a certain number of the more hardy harmless forms may be carried bodily over with the steam into the condensers.

In most of the ice-manufactories the distilled water is filtered through charcoal before it is run into the freezing-cans, for the purpose of removing certain organic compounds which have come in the process of distillation. But these charcoal beds afford breeding-places for such germs as may have escaped the ordeal of the heat. The writer has repeatedly found that while the distilled water before passing on to the filter beds was very nearly germ free, the number was increased a thousandfold on leaving them.

So far as the salubrity of the natural as compared with the artificial ice is concerned, we may rest assured that as regards bacteria, one is just as wholesome as the other, provided the water used is pure. If the water is impure from sewage or other unwholesome thing, then the natural ice is never fit for domestic use. If water is impure, the processes of artificial ice-making, if carefully performed, are capable of furnishing even from it a product which is harmless and wholesome, whether it be absolutely germ free or not; for absolute freedom from germs—if these are not disease-producing forms—is neither necessary nor especially desirable. *It is not bacteria, but disease-producing bacteria, which make of practical significance the invisible flora of either water or ice.*

The examinations of artificial ice made from the distilled Croton water have shown that when it does contain a few bacteria these are not of many different species, as is the case with the undistilled Croton, but they are almost all of one single species, and this a hardy, harmless form which multiplies readily and rapidly in pure water.

Innumerable analyses have shown that water does not purge itself wholly in the act of freezing, as was formerly believed, from disease germs which may have come into it with human waste. This has been specifically and repeatedly shown to be true for that most dreaded and fatal sewage germ, the bacillus of typhoid fever.

The process of oxidation and sedimentation, which aforetime was demonstrated by most exact chemical analyses to be capable of freeing water in lakes and running streams from organic compounds abundant in sewage, is still urged by belated scientists and frantic tradesmen here and there in justification of the use of ice cut on sewage-polluted waters. But these facts regarding the organic products of decomposition have very little bearing, in the new light, upon the actual producers of disease—the germs themselves. For these are not subject to the same purifying agencies, are not demonstrable by chemical methods, and are not removed from sewage-polluted lakes and streams within the limits which chemical experiences have led us to regard as safe.

Sedimentation does remove many harmful germs from sewage-polluted waters. Dilution does diminish the chances to incur disease for every consumer. Many individuals are, at favored times, practically invulnerable to the incursions of these tiny foes. But, after all, it is safe to say that in thickly inhabited regions sewage-polluted water is not fit for men to drink without purification, no matter how fast and far the river runs, or how wide the lake into which the sewage drains. With the size of the lake and the volume of the river, the chances of harm decrease, of course, but they stay chances still where none need to be. As our country becomes more thickly settled and our cities larger, the problems involved in pure water and ice supplies are becoming more and more urgent and difficult.

The manufacture of ice and its marketing at prices which in many regions easily compete with those of the natural product have simplified this phase of the water question in the most marked way. Other things being equal, whether the householder decides to use the natural or the artificial ice will depend much upon the climate of his home and the market price of the ice. The natural ice is just as good as the artificial when it comes from pure sources. It is claimed by some that the natural ice melts more slowly than the artificial, and is in this way, other things being equal, cheaper. But similar claims are made for the artificial ice. The writer has tested the relative rapidity of melting of the natural and the artificial ice in New York under the greatest variety of conditions; in small pieces and in large, in the dark, in the light, in diffused light and in the sunshine, in hot places and in cool, and can find no absolute constant difference in the rapidity of melting. One seems to be just about as durable as the other.

New York city is one of the most striking examples of a great town which takes extraordinary pains, or at least spends enormous sums of money, in keeping its sanitary conditions good. It has an almost ideal water supply, which, if properly and efficiently protected, would long answer its growing needs. Its means for coping with outbreaks of serious epidemic disease are carefully planned. And yet this great, wealthy, and seemingly intelligent community goes on year after year polluting its own excellent water with the frozen filth of a great sewage-polluted river.

One may even sometimes see citizens of this metropolis, keenly alive to the advantages of cleanliness, and insisting upon the use of distilled water at their tables, yet calmly plump into their glasses of pure water the frozen sewage of the upper Hudson from the vicinage of Albany and Troy.

We know that typhoid fever is nearly always present in Troy and Albany during the ice-harvesting season. We know that the waste from these victims of disease is cast into the Hudson River. We know that the typhoid germ resists freezing and long-continued cold, and yet between seven and eight hundred thousand tons of ice are cut from the Hudson in average years within twelve miles of Albany, largely for the refreshment of New-Yorkers.

A good deal of the natural ice supplied to New York comes from other sources—many of them better, some unquestionably good. But, so far as I am aware, the householder cannot receive positive assurance that his supply will not be, at any rate during a part of the year, from the polluted Hudson.

In this condition of affairs it does not seem clear to the writer why any New York householder should long hesitate between the use of artificial ice made from the Croton water and the abundant chances for evil which lurk in the sewage ice of the Hudson River.

I have written thus at length of one great source of polluted ice supply, because it is typical of many in this country. And the indifference of the citizens of New York in this respect is not without analogy among the citizens of other towns, both small and large.

My readers will, I am sure, deplore with me the necessity for weaving the shadow of disease into so dainty a theme as ice and its manufacture.

JANE FIELD.*

BY MARY E. WILKINS.

CHAPTER V.

ELLIOT was only a little way from the coast, and sometimes seemed to be pervaded by the very spirit of the sea. The air would be full of salt vigor, the horizon sky take on the level, outreaching blue of a water distance, and the clouds stand one way like white sails.

The next morning Lois sat on the front door-step of the Maxwell house, between the pillars of the porch. She bent over, leaning her elbows on her knees, making a cup of her hands, in which she rested her little face. She could smell the sea, and also the pines in the yard. There were many old pine-trees, and their soft musical roar sounded high overhead. The spring air in Green River had been full of sweet moisture and earthiness from these steaming meadow-lands. Always in Green River, above the almond scent of the flowering trees and the live breath of the new grass, came that earthy, moist odor, like a reminder of the grave. Here in Elliot one smelled the spring above the earth.

The gate clicked, and a woman came up the curving path with a kind of clumsy dignity. She was tall and narrow-shouldered, but heavy-hipped; her black skirt flounced as she walked. She stopped in front of Lois, and looked at her hesitatingly. Lois arose.

"Good-mornin'," said the woman. Her voice was gentle; she cleared her throat a little after she spoke.

"Good-morning," returned Lois, faintly.

"Is Mis' Maxwell to home?"

Lois stared at her.

"Is Mis' Maxwell to home? I heard she'd come here to live," repeated the woman, in a deprecating way. She smoothed down the folds of her over-skirt.

Lois started; the color spread over her face and neck. "No, she isn't at home," she said, sharply.

"Do you know when she will be?"

"No, I don't."

The woman's face also was flushed. She turned about with a little flirt, when suddenly a door slammed somewhere in the house. The woman faced about, with a look of indignant surprise.

Lois said nothing. She opened the front door and went into the house, straight through to the kitchen, where her mother was preparing breakfast. "There's a woman out there," she said.

"Who is it?"

"I don't know. She wants to see—Mrs. Maxwell."

Lois looked full at her mother; her eyes were like an angel's before evil. Mrs. Field looked back at her. Then she turned toward the door.

Lois caught hold of her mother's dress. Mrs. Field twitched it away fiercely, and passed on into the sitting-room. The woman stood there waiting. She had followed Lois in.

"How do you do, Mis' Maxwell?" she said.

"I'm pretty well, thank you," replied Mrs. Field, looking at her with stiff inquiry.

The woman had a pale, pretty face, and stood with a sturdy set-back on her heels. "I guess you don't know me, Mis' Maxwell," said she, smiling deprecatingly.

Mrs. Field tried to smile, but her lips were too stiff. "I guess I—don't," she faltered.

The smile faded from the woman's face. She cast an anxious glance at her own face in the glass over the mantel-shelf: she had placed herself so she could see it. "I 'ain't got quite so much color as I used to have," she said, "but I 'ain't thought I'd changed much other ways. Some days I have more color. I know I 'ain't this mornin'. I 'ain't had very good health. Maybe that's the reason you don't know me."

Mrs. Field muttered a feeble assent.

"I'd known you anywhere, but you didn't have any color to lose to make a difference. You've always looked jest the way you do now since I've known you. I lived in this house a whole year with you once. I come here to live after Mr. Maxwell's wife died. My name is Jay."

Mrs. Field stood staring. The woman, who had been looking in the glass while she talked, gave her front hair a little

* Begun in May number, 1892.