other in rapid succession during the summer; but this immense expanse of sea will also have a modifying influence upon the winter temperatures, and we may expect to find the coldest periods milder than the Arctic winter. The average precipitation, snow and rain fall, will probably be much greater than in the north, but the annual temperature cannot be much lower.

While we are pondering of this mysterious Antarctic land of the present, if we look for records of past life, we find to our surprise that there is evidence quite sufficient to prove that sunshine and warmth were once abundant where now all is cold desolation. Captain Larsen found at an elevation of about 300 feet large petrified trees with roots, limbs and bark in an excellent state of preservation, and he said that "the pieces of fossil wood increased as he advanced inland on Seymour Island, and that they were in a position and of a character that they could not have been thrown out of the sea." He also found in the debris that fell from the stratified cliffs fossils, probably belonging to the Tertiary age, resembling some described by Darwin from Patagonia.

These are the first positive evidences of land life from the Antarctic, and while the record is meager in the extreme, it nevertheless opens up a wonderful field for speculation and investigation.

As we examine the ocean bed, we find that a continuous layer of bony material is deposited over the whole bottom of the southern sea, revealing to us a graveyard of countless known and unknown forms of life that have contributed their skeletons during a period extending over thousands of years.

As I complete this picture of that distant icy bottom of our globe, where all longitudes cross each other, and latitudes disappear, using about all of the definite information at our command, and before we launch farther into the field of conjecture and possibilities, it must be evident that a great transformation has taken place, for what must have been the atmospheric and other conditions to permit the growth of trees and a previous fauna, as is shown by the unquestionable fossil finds?

While we are amazed by this almost supernatural metamorphosis and its grandeur, we naturally look for an explanation; the astronomer steps forward—he whose figures we have long learned to regard as cold facts, and whose mathematics have won for him the title of a true prophet. With a keen eye he directs us to a prehistoric ice age; during recent times (as the astronomer figures, though this be thousands of years), caused by a number of eccentricities of the orbit in which the earth travels around the sun, and he says that the earth has not only undergone one such transformation, but several; and that at present we are undergoing such changes, or ought to be, at both the top and bottom of the globe. The southern hemisphere should be advancing into an ice age when the glaciers will extend well into the south temperate zones, while the cold seal of the north will be removed in ten thousand years, more or less.

Then a brilliant but periodical sunshine and a genial warmth will again reign where now all is a sealed icy desert. The climate of the north, even at the north pole, will be warm and congenial. The waters will be navigable, and, no doubt, the Arctic lands will be clothed by a luxuriant verdure, such as sweet smelling flowers and edible plants, perhaps even trees.

At that time, too, the climate here will assume a tropical aspect and we will be glad to go to the north pole to enjoy the cool breezes during the nightless days of the Arctic summer, or we may then direct our attention to the then endless sheet of ice as it advances over the Southern Hemisphere.

In awe and amazement the future races will then behold the slowly moving crystal torrent, exerting its destructive and irresistible force over South America and Africa, as it is doing to-day in the Antarctic.

If we need further confirmation to prove this theory, the geologist and paleontologist will help us out, furnishing the missing links.

Under the colossal sheets of ice and snow in the north, as far as man has penetrated, we find abundant evidence of a previous age of heat and life. Fossil remains of pond lilies, ferns, reeds and other semi-tropical plants that are even too frail to withstand the rigors of a temperate climate; these have thrived within a few hundred miles of the north pole in ages past.

The widely diffused beds of coal, the petrified woods, the indisputable fossil impressions of both the Arctic and Antarctic, prove beyond question that the polar regions have undergone congenial periods, while the colossal remains of mammoths in Northern Siberia and Alaska indicate the stately forms of animal life that ruled supreme in those distant preglacial times.

Such periods have occurred, and the astronomer predicts with much scientific precision that we shall again return to similar conditions.

THE CAUSE OF THE MOVEMENT OF GLACIERS.

By P. L. ADDISON, F.G.S., Assoc. M. Inst. C.E.

To some readers there may not at first appear anything very interesting in the movement of glaciers. Such is, however, the case with many of the phenomena in Nature, and it is not till we seek to unravel the intricate relationship in the family of physical forces, which produce great changes on the face of the earth, that the interest becomes absorbed in that which we thought worth little attention.

There is something so profoundly mysterious in the regular method employed by Nature in carrying out her designs, that if we simply recognize her work, without even in a superficial manner investigating the method by which it is produced, the "pith and moment" is all but lost; we, in fact, but look on the outside cover of a book of fairy tales without enjoying the charming stories it contains, and thus leave the "Rhymes of the Universe" unread.

We are familiar with the appearance of glaciers as they lie in valleys and mountain clefts, and have observed how, if two valleys converge and join one another, the ice sheets they contain combine in one mass, as two rivers would do, although the ice forming the glaciers is often several hundred feet in thickness,

and seems to be an inert mass of solid matter. There is no doubt, however, that a glacier moves down the valley very much in the same way as a river, but, of course, more slowly. The motion is quicker on the surface, and slower at the bottom and at the sides. But we must not carry this comparison any further; the physical conditions of the two streams are not the same, and their motion, though in many respects similar, is widely different in degree and origin.

It is hardly necessary to point out that a glacier does not slide down the valley which contains it. The well proved differential movement, the inequalities of the ground over which it passes, and the bends round which it has to turn, render sliding motion impossible, and besides this, the apparently rigid glacier creeps down slopes on which soft clay or loose shingle remain practically immovable.

If we examine a piece of ice, say for example an icicle, we find that it is exceedingly brittle; if thrown down upon the ground, it breaks into many pieces. A piece of soft clay can be bent or compressed into any shape with ease, and yet an ice sheet, of exactly the same composition as the icicle, will steadily flow down slopes so gentle that soft clay will stand on them without moving at all. When a bed of clay moves down a hillside the particles of which it is composed slide past and roll over each other till they come to a state of rest at the bottom, but as the ice could not behave in this manner, other causes must be sought to account for glacier motion.

There is a peculiar irregularity in the movement of glaciers, which probably first led to the discovery of the cause, and this is that the motion is quicker during the day than at night, and the summer rate is often double that attained during the winter. This shows that pressure from behind cannot be the cause of the motion, for, through the greater accumulation of ice and snow on the higher levels, the pressure must be greater during the winter season when the movement is least. The fact that the motion of the ice sheet is greater during the day than in the night, and in summer than during winter, naturally leads us to conclude that heat must indirectly have something to do with the phenomenon, for the movement is greatest during that part of the twenty-four hours when the ice is subjected to the sun's rays, and in the warmer seasons of the year. An examination of the physical properties of the glacier will show how it can be affected by heat and yet, as a mass, remain in the form of ice.

When a thin slab of ice is subjected to microscopical examination, it will be seen that it is not, as it appears to the naked eye, a homogeneous mass of solidified water, but a confused agglomeration of minute crystals, with cavities equally minute lying between them. A glacier is simply water in a crystalline state, and any motion in the mass involves the movement of the crystals of which it is composed.

It has already been mentioned that the flow of the ice sheet is quickest at the center and on the surface, and slowest at the bottom and against the sides of the valley; it follows, therefore, as the motion is differential, that the ice crystals in the center of the glacier must pass by those composing the sides and bottom. This appears to raise a difficulty, for if the minute crystals were to crush past one another, owing to their traveling at different speeds, they would soon be ground to a fine powder. This does not, however, take place, and the ice sheet remains a solid and brittle mass.

We know that water freezes at a temperature of 32° Fah. and in doing so it gives out a certain amount of heat and assumes a crystalline form, and at the same time expands about ten per cent. in volume. In other words, one cubic foot of ice at 32° Fah. will only make 0.908 of a cubic foot of water at the same temperature, and a cubic foot of water 32° Fah. will expand to 1.102 cubic feet of ice. If, therefore, water is compelled to assume a solid condition, a mechanical force is at once exerted through the necessary expansion of the substance in freezing. An experiment was tried to keep water while it froze inclosed in an iron bombshell thirteen inches in diameter. The shell was filled with water and the hole securely stopped up with an iron plug weighing three pounds. When the freezing process began the water expanded, and something had to give way in order to provide accommodation for its increased bulk. So great was the force exerted that the plug burst from the shell with a loud report and was projected to a distance of nearly one hundred and forty yards, and the ice protruded from the plug hole in the shape of an icicle eight inches in length. Another shell was filled in a similar way, and the plug was more securely fastened, but when the water froze the shell burst, and the ice spread out all over the cracks. The mechanical force exerted in both these experiments was unmistakable.

But let us note the peculiar behavior of the ice. In the one case it spurts out from the plug hole and remains there, joined with the ice inside the shell, a brittle icicle eight inches long. If the ice had been of the consistency of putty, this form of protrusion is what one would have expected, but when it occurs in a brittle and crystalline substance, it demands thought and consideration.

On account of the very low temperature to which the shells were subjected, the greater part of the contents would be formed into ice. This is indeed a necessary condition in order that sufficient pressure might be exerted to prevent all the water from freezing. Inside the shells there would be a crystalline mass, the minute interstices of which would be filled with molecules of liquid water ready to freeze the moment the pressure acting on them was reduced. This moment arrived when the shells gave way. The molecules of water began to assume a crystalline form, some in the interspaces and some outside. The compressed water spread over the cracks, and through the plughole in the shells, and there instantly turned into ice, while other molecules of water inside, becoming solid, pushed with irresistible force in all directions the crystals already formed. Thus there was an expenditure of energy, and an amount of work done by the water in giving up heat it had derived from the sun, and in assuming a crystalline condition.

In order to make this point more clear, we may briefly mention another well known experiment with water and ice.

Take a pound of water, the temperature of which is 80° on the Centigrade thermometer scale, and mix it

with a pound of water at 0°, or freezing point; the mixture will make two pounds of water, the temperature of which is 40° Centigrade.

Now take another pound of water at 0° Centigrade, and mix with it a pound of crushed ice—that is, ice crystals—at 0° Centigrade, the same temperature as the cold water in the first mixture, and the result is that we have two pounds of water at freezing point.

In both cases the weight of matter at 0° Centigrade introduced into the warm water was the same; how then is it that in the latter experiment the water is reduced 40° lower than in the former? Before the ice crystals could assume a liquid condition they had to absorb a certain amount of heat. That heat was drawn from the warm water, and consequently reduced its temperature, but it did not raise the temperature of the ice; it simply acted as energy in enabling the ice to become liquid, and remained in that liquid in the form of latent heat, to be given up again as soon as the water reassumed a crystalline form. One other question may very naturally occur to the reader, namely, if heat is required to melt ice, how is it that water and ice can exist separately at the same temperature? In the first place, water at freezing point is in an incipient state of crystallization; and secondly, from the commencement to the end of solidification the temperature of a liquid remains constant.

Let us now attempt to apply the foregoing principles of the expansion of ice on a small scale to the movement of glaciers, and other great ice sheets.

The sun, in expending its rays on the surface of the glacier, does not raise the temperature of the ice of which it is composed; it, however, imparts energy, which, with gravitation, causes the glacier to move along that path where, as a whole, it finds least resistance to its motion.

The method may be thus described: The heat of the sun melts the ice on the surface of the glacier, and it contracts in bulk on becoming liquid, and flows downward by the aid of gravitation into the interstices between the ice crystals below. Here the water is no longer influenced by the sun's rays, and again becomes crystalline, but the crannies and corners into which it has found its way are not suitable in shape to contain it in the form of crystals, and therefore in parting with its heat it employs that irresistible force due to crystallization to make the cavities larger. In other words, it pushes away the molecules surrounding it down the path of least resistance. But we must not forget that the molecules of water on becoming recrystallized part with latent heat. This heat is taken up by adjacent molecules of ice, which, in their turn, become water, flow downward and exert pressure in the process of recrystallization. Thus, little by little, and from molecule to molecule, the heat derived from the sun is transmitted through the length and breadth of the glacier. The action is not at one place alone, but permeates the whole mass. We must look upon the glacier as an agglomeration of moving molecules, which, having utilized gravitation to enable them to flow downward when in a liquid state, follow up that movement by an overpowering pressure produced during their process of recrystallization.

But how is it, if a glacier is constantly receiving heat on its surface which passes through its entire thickness, that it does not in time all melt? Like other rivers, glaciers are constantly being fed with fresh material from their sources and by tributaries, and this supply neutralizes the waste which actually does take place, and which is represented by the terminal streams of water—the origin of some of the greatest rivers in the world. A glacier receives heat and energy from other sources than the direct rays of the sun on its surface. Radiation from the earth, and tepid water entering the larger fissures of the ice, convey heat into the interior which, in its action, produces exactly similar effects to those caused by the direct rays of the sun.

If this molecular theory of the movement of ice is the true one, there is no difficulty in accounting for the peculiar manner in which glaciers adapt their shape to the inequalities of the ground over which they flow. It is true that crevasses may be formed, owing to a sudden alteration of slope producing a transverse strain across an ice stream and thus breaking it in two or forming deep cracks (to be healed, eventually, by the process of regelation) before the molecular movement can adapt the glacier to the form it is required to take; but if time is allowed, ice has shown itself to possess wonderful qualities in adapting itself to the nature of the valleys in which it moves.

Perhaps the most striking examples of this kind are furnished, not by existing glaciers, but by those of the last glacial period, when on Northern Europe the land ice extended much farther south than it does at present, and was of enormous weight and thickness. During that period, rock basins, which now form large lakes, were filled with ice, and in some instances it has been shown that they were carved out of hard rock by glacial action.

The directions in which the ice moved during this cold period in Northern Europe is ascertained from the marks it caused to be made on the hard rocks over which it passed. The striæ are a certain indication of the trend of the ice flow, and prove that the ice not only traveled down the slope into the rock basin, but that it also rose up the slope at the other end, although the surface of the glacier might be several hundred feet above.

This fact demonstrates more conclusively than any other example that could be given, the complex molecular movement in every part of a glacier. If the ice had moved by pressure from behind, and by gravitation, as it would affect a mass of plastic clay, it would have first filled the lake basin, and then continued to flow over the top. But this was not the case. It moved on the top, it moved in the middle, and it moved at the bottom; each molecule in the entire mass was constantly taking in energy from heat and acting alone, and giving out energy and acting in conjunction with its neighbors in converting that energy into motion.

With regard to the striated surface of some of the harder rocks over which a glacier has in bygone ages flowed, it might at first be thought that these markings pointed more to a sliding than to molecular motion. It must, however, be remembered that the striæ are produced, not by the ice itself, but by graving tools in the form of stones, which it carries with it in its general motion. These stones, loosened from the

ground, become embedded in the ice, cutting and grooving the solid rock surfaces beneath, they themselves being ground down in the process.

There is another circumstance which tends to prove that glaciers in their interior are not inert masses of ice. This is the habit they have of disgorging stones and other foreign matter on their surface. An example of this tendency is that a knapsack, having been dropped into a crevasse, found its way to the surface of a confluent glacier ten years later, and more than three quarters of a mile from the place where it had been lost.

There is, it appears, no means of arresting the movement of glaciers except by cutting off entirely their supply of heat, and this for a sufficient time to allow them to get rid of that which they have already absorbed.

Perhaps the most interesting direction in which these considerations lead us is toward the study of the action of glaciers and ice sheets during the last and former glacial periods. Evidence of this action is to be found on every hand, and it is often strange to think as we stand in the warm sunshine in a pleasant wooded valley, decked with every variety of vegetation, that about the time when man apparently first appeared on the earth the place lay hundreds of feet below a great sea of ice which overspread Northern Europe.

Enough has been said to draw the attention of the reader to the means employed by Nature for carrying out the work which she desires to perform. She employs no labor nor constructs elaborate machines to do her will, but, through the reciprocal relationship of the physical forces, causes great changes to take place in the universe, which, simple as they may seem to be in the abstract, like the movement of glaciers, are, though complex in the extreme, superbly accurate and efficient in every detail.—Knowledge.

BROOKS' NEW FORM OF REFLECTOR TELESCOPE.

DR. BROOKS writes to the English Mechanic as follows:

In 1884 I was engaged in repolishing and refiguring the metal speculum of a Herschelian reflector, then the property of Hobart College, in this place. It was of 7 in. aperture and about 10 ft. focal length.

While the speculum was in my keeping I made trials of numerous combinations, among them the Cassegrainian. As there was no central hole in the speculum, I was obliged to receive the rays reflected backward from the convex mirror, on one side of the large speculum. All parts were attached to a flat board by pivots and screws, giving every facility for adjustment. The convex mirror was a 3 in. diameter lens, silvered on its front surface. A flat mirror of about the same

size was also tried in place of the convex with good results, no change in the focus of the combination being produced in the use of the flat, and this in some respects would be an advantage.

Finally, the convex mirror or flat, whichever was being used, was placed to one side of the rays coming from the object, thus leaving the large speculum unobstructed. The large speculum was tilted toward the small one, and the small mirror, whether convex or flat, was inclined, so that the distortion caused by the tilting of the large speculum was corrected, and the image was sent to the eyepiece with perfect definition.

THE BROOKSIAN REFLECTOR.

The arrangement is shown so plainly in the above diagram as to need no further description. Its many advantages are also apparent. The large speculum is not obstructed, the distortion caused by the inclination of the large speculum is corrected by the proper inclination of the small one, and the length of the instrument is reduced to about one-half of the focus of the large mirror.

In harmony with the nomenclature of the subject, I named this telescope, when I invented it eleven years ago, the Brooksonian reflector, and should I prove to be the prior inventor, I shall be glad if my astronomical brethren will adopt the name.

WILLIAM R. BROOKS, F.R.A.S.
Smith Observatory, Geneva, N. Y.

THE ECLIPSES OF 1895.

THE eclipses of the 11th and the 26th of March, or of the vernal equinox, are of greater interest than those, their counterparts, of the autumnal equinox, occurring on the 4th and 18th of September. The partial solar eclipse of the 26th of March is not visible in the southeast of England—only as a mere fractional phenomenon in the north and west of Britain—and will be but of little general interest here, though it may attract some notice from travelers crossing the Atlantic on that date, as about a third of the sun's disk will be hidden during the maximum phase to be seen on the Canadian side. The solar eclipse of the 20th of August will not be visible here, nor will that of the 18th of September, which, in fact, will be of in-

terest to the inhabitants of the southern hemisphere only. The total eclipse of the moon of September 4th—so similar in other respects to that of the 11th of March—falls in interest in these islands, as the moon sets during the total phase, and it is only the "blotting-out process" that will be seen.

EXPLANATION OF THE DIAGRAM.

The mutual positions and relations of the three bodies—sun, earth and moon—are shown on the diagram for each of the five eclipses of the year. The drawing represents in perspective a zone of the celestial sphere treated as a cylinder. Upon it are laid down the apparent motion of the sun in the heavens during the year, and the motion of the moon as it appears to us during the first four weeks of the present month. The earth, as the position of the observer, is represented as stationary in the center of the zone, the moon's orbit being also shown there. In the case of the lunar eclipse on the 11th, the sun is shown in its position for that date on the nearer portion of the cylinder. A strong black line carried from it to the earth in the center, then beyond to the moon in its orbit, and continued to the apparent position of that body shown on the distant side of the cylinder, connects the three factors of the phenomenon, and will serve to indicate, on one side, the sheaf of sun's rays passing to the earth, and beyond that body the central line of the shadow thrown by the earth, on that date, cast upon its satellite. On the diagram the shadow is emphasized at A. The second lunar eclipse of the year—that of September 4th—is shown in the same way, but the sun then being in the opposite quarter of the heavens, the eclipsed moon appears on the nearer half of the zone. In this case the earth's shadow is indicated at B. In the solar phenomena the moon's body is shown interposed between the sun and the earth, and the eclipse consequent on that obstruction is in each case depicted on the sun's face. The maximum phase as on the earth generally is given, and not that for our islands.—London Daily Graphic.

[FROM THE ASTROPHYSICAL JOURNAL]

ARTHUR COWPER RANYARD.

It is with deep regret that we record the death of Mr. A. C. Ranyard, which occurred at his home in London on December 14, 1894. Arthur Cowper Ranyard was born in 1845. In his early life he was much influenced by De Morgan, from whom he received part of his mathematical training. In 1868 he took his degree at Cambridge, and three years later he was called to the bar at Lincoln's Inn, where he continued to practice his profession until shortly before his death.

But while busied with his legal duties, he found time for much work in mathematics and astronomy. From the time of his election as a fellow of the Royal Astronomical Society in his eighteenth year until the beginning of his last illness, he was one of its most active and faithful members. As honorary secretary from 1874 to 1880, and as a member of the council for twenty years, he contributed as few men have done to make the influence of the society what it is to-day. The London Mathematical Society was established partly through his efforts, and he served it also as an honorary secretary. His contributions to astrophysics have been numerous and valuable. Few of the memoirs of the Royal Astronomical Society are so frequently consulted as Volume XXI, in which he brought together the observations of total eclipses of the sun up to 1875. This is an invaluable work to solar physicists.

After Mr. Proctor's death he undertook to complete the unfinished volume of the Old and New Astronomy and to edit Knowledge. In the former the chapters added by Mr. Ranyard are the most valuable portions of the book. Knowledge, too, was much improved under his editorship, and by his plan of publishing photographic reproductions of the best astronomical photographs, students were for the first time enabled to obtain these valuable records. The broad and generous nature of the man is shown by the way in which he sacrificed personal interests and devoted himself to the task of carrying to completion the work of another. His association in editing De Morgan's Newton is a further example of the same spirit.

His papers dealt with a wide range of subjects. Solar phenomena particularly attracted him, and he brought forward much evidence to show that prominences are projected into a resisting medium, and that a true solar "atmosphere" does not exist. He contended that the gases surrounding the sun show no such increase in density near the photosphere as they would if the lower layers supported those above them. In the forms of certain nebulae he detected remarkable analogies with those of solar prominences. The dark areas on long-exposure photographs of the Milky Way and other parts of the sky he considered to be masses of absorbing gas between us and the brighter nebulae. He devoted much study to the question of the structure of the universe; his treatment of this subject may be found in the Old and New Astronomy.

As an investigator he did much good work, especially at the solar eclipses of 1870, 1878 and 1882. His very active life left him so little opportunity for research that just before his death he was planning to establish a large observatory, and to devote his entire time to astrophysical investigation. The spectroheliograph which had been used in the recent attempts to photograph the corona at the observatory on Mount Etna was to be attached to his reflecting telescope for work on the sun, and a large reflector of novel and ingenious design was to be devoted to stellar spectroscopy. But his death occurred while the details of these plans were under consideration.

In his many-sided life his kindly nature and wide sympathies brought him many warm friends. They will keenly feel his loss. G. E. H.

CRAMPS AS A SIGN OF DIABETES.

DR. UNSHUL has called attention to a symptom which I have been for many years familiar with, and ought long ago to have recorded, namely, cramps in the lower limbs in cases of diabetes. He says the symptom occurs in 21 per cent. of cases. I have not reckoned it up in this manner, but I suspect he is near to the truth. I agree with him in observation that the

THE ECLIPSES OF 1895—DIAGRAM SHOWING THE MUTUAL RELATIONS OF THE SUN, EARTH, AND MOON FOR EACH OF THE FIVE ECLIPSES OF THE YEAR.