have been long since expelled from their responsible positions. The remaining acts complained of have been done in pursuance of the general policy just outlined. It seems equally clear that these complaints, though natural, are unjust. The residuary legatees have now $192,000 to divide. It is not long since they had nothing. Science is certainly grateful to the trustees, since their economical policy has already saved a large sum which will eventually go to making the California academy of sciences more powerful and useful than it now is.

With regard to the other bequest in which science is interested, — namely, the Lick observatory, — there is every reason to be extremely grateful to the trustees for their wise administration of the trust.

Their economy has certainly been remarkable. They have expended on the observatory to Oct. 1, 1883, $154,527.98; and they have remaining $545,472.02. This $155,000 has done the following things: the top of a bleak mountain four thousand feet above the sea, and twenty-seven miles from a town, has been levelled off so as to give a sufficient area for the buildings (forty thousand tons of rock have been removed for this purpose alone); brick enough to complete the whole of the buildings has been made on the side of the mountain, and delivered at the top, at a total cost less than the price of hauling the same amount from the nearest town; a handsome and well-built main building is now nearly finished (the large dome alone remains; a small dome, containing a very perfect twelve-inch equatorial by Clark, has been in use since November, 1881); a four-inch transit instrument, in a convenient house, is in complete working-order; a photoheliograph in a permanent house has been in use since December, 1882; the house for the meridian circle is begun; the meridian circle is half paid for, and a payment has been made on the large telescope. This is the work which is to be seen on the mountain-top proper. Just below this are the houses for the workmen, shops, stables, etc., all in good condition, and a very complete system of water-supply in full working-order.

It will appear to any competent person that this work has been done thoroughly, and that it has been done economically. At the same rate of expenditure, at least $300,000 will remain as a permanent fund for the support of the observatory.

It therefore appears that the trustees have deserved well of science in their administration of their trust, not only in regard to the California academy of sciences, but also in relation to the Lick observatory; and it should be the desire of all interested in the administration of this trust to strengthen the hands of the trustees in the continuance of their wise policy.

WHIRLWINDS, CYCLONES, AND TORNADOES.[1] — II.

The further growth of the desert-whirl may be briefly described. The air standing quietly on a flat, dry surface allows the lower strata to be quickly warmed to a high temperature. If the air were in motion, no part of it would remain long enough close to the ground to be greatly warmed; if the surface were not flat, the lower air would flow up the slopes as soon as it was a little heated, and not wait to acquire a high temperature; if the surface were wet, much of the sun's heat would be occupied in evaporating the water (as will be explained below), and would so be lost to the lower air: it is therefore only in calm weather, on a desert plain, that the sun can succeed in warming the lower air to excess, and so produce a very unstable equilibrium, and a strong updraught when the upsetting begins. The longer the delay before the overturning, the more heat-energy is accumulated, and the more violent the motion when it begins. The lower air rises at some point against the oppression of the upper layers. The surrounding warm air flows in from all sides toward this central point, and follows the leader. Soon the motion becomes general and lively, dust and sand are blown along toward the centre, lifted and carried aloft with the ascending air in its rapidly rising current, and then the whirling column becomes visible. When thus established, the increased velocity and the rotary motion of the air near the centre are constant characteristics of the upsetting. Thirty

[1] Continued from No. 39.

or forty feet to one side, the wind may not be strong enough to brush along the sand, and a few hundred feet away it may not be perceptible; but at the centre it makes a distinct rushing or roaring sound, and carries light objects upwards, sometimes to a height of several thousand feet. This increase of velocity of the surface indraught toward the point of its upward escape is a general feature of the motion of a mass of free particles along a path of varying width: the narrower the path, the faster the motion. The same increase is seen in the growing velocity of a stream running out of a lake, so beautifully shown where the Rhone flows from Lake Geneva, or, more simply and prosaically, in the running of water from a tub by the escape-pipe. In the case of a desert-whirl, the central wind is held by friction with the surface sands much below the velocity it might attain; for it must be remembered that these whirls are supplied by a comparatively thin layer of superheated air next to the ground, often not more than four or five feet thick. The restraint of friction on such a layer will be very considerable, and its motion can seldom reach a disastrous strength. It is probable that in the desert sand-storms, which are described as overwhelming caravans, there is a much thicker mass of air in activity, and the conditions of motion approach those of the tornado, as will be shown farther on.

The second characteristic feature of the wind's motion gives name to the storm. A whirl must necessarily be formed when the air moves inwards from all sides towards a centre, for the indraughts will surely fail to follow precisely radial lines. Their aim will be a little inexact; and, as they pass to one side or the other of the centre, a turning must begin in a direction determined by the strongest current. This, once begun, is maintained by the centrifugal force that arises from it; and the size of the central whirl will then depend on the balance between the centripetal and centrifugal forces. In ascending at the centre, the wind follows an upward spiral course, like the thread of a screw of steep pitch, with a diameter of five to twenty feet. The direction of turning is indifferently one way or the other, according to the side on which the indraught happens to pass the centre. The height to which the whirling column rises will be determined by its mixture with the adjoining air, and consequent cooling until its temperature is that of indifferent equilibrium; and at this elevation the current will turn and spread laterally to make room for that which follows. Such a whirl will continue as long as its cause lasts; that is, as long as it is supplied with warm air at the base.

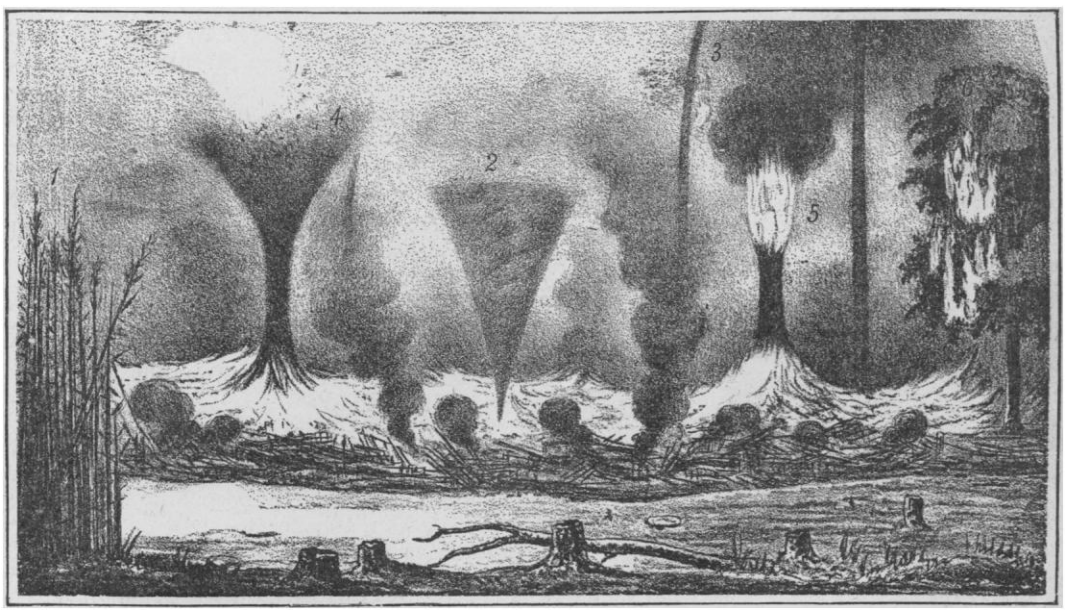

FIG. 3. (Taken from *Amer. journ. sc.*, 1851.)

Manifestly it must stop in the afternoon, as the sun's heat decreases; and it can never occur at night, for then the surface-air is, as a rule, cooler than that above, and the atmospheric equilibrium is correspondingly stable. Further, the whirl will remain at one place, unless, as is often the case, it is carried along by a general motion of the upper air.

There is a very strong point of evidence, if any is needed, in favor of the view that heat applied to the lower layers of the air will produce a whirlwind. This is the fact of their pro-

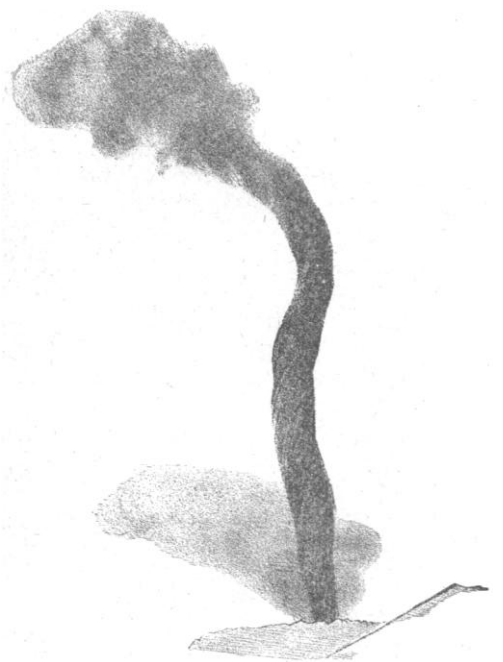

Fig. 4. (Taken from *Abhandl. gesellsch. wiss. Gött.*)

duction over fires. Much interest was excited in this question in connection with the artificial causing of rain, some forty years ago, in this country; and observations were carefully made of the whirls formed over burning woods and canebrakes, showing them to be very similar in form and action to those naturally arising on dry plains (fig. 3). Similar whirls have been seen over volcanoes (fig. 4); and on a calm day the smoke ascending from a factory chimney may be seen to have a slow rotary motion. Heat is therefore an amply sufficient cause of such disturbances. No other excitement is needed, and electricity has no essential part to play. In recognizing this, we see the chief difference between the older and newer theories of storms.

Sand-whirls are common in all desert or dry regions, where they often have the name of spirits or devils, from the fantastic and apparently evil way in which they flit across the burning sands. They have neither clouds nor rain. When well and frequently developed, they may grow to dangerous strength, and lift much dust and sand into the upper air, where it is blown long distances before falling. In this way they serve as important geologic agents. Vessels west of the Sahara, or east of China, are thus often powdered over with fine dust slowly settling down after a long flight from its desert source.

The smaller water-spouts, doubtless, belong near here in our scheme of classification; but as they are usually aided by vapor-force, and approach the character of tornadoes, their consideration is best deferred till later.

Finally, before going on to the larger storms, one point of much importance must be emphasized. The change from the stable equilibrium of night and early morning to the unstable of noon is effected entirely by the sun's heat, which warms the lower air, and causes it to expand. In expanding, it lifts all the upper air that rests on it; and this is no small piece of work, for the air that is lifted weighs about a ton over every square foot. When a point of escape is found, the heavy upper air sinks again, as the expanded air is drained off (upwards) at the centre. It is this gravitative force of the sinking air-mass that causes the dust-whirlwind, in re-arranging the disturbed equilibrium of the atmosphere; but gravity would have no chance to show its strength, if the air had not been lifted by force from the sun. The winds of a dust-storm, therefore, depend on gravitative force brought into play by the sun's heat. All storms and all winds have more or less closely this relation to solar energy and terrestrial gravity.

(To be continued.)

THE INTERNATIONAL FISHERIES EXHIBITION.—FOURTH PAPER.

On the 1st of October, at noon, the number of visitors to the exhibition passed the much desired limit of two millions; and, although the rainy season had set in, the daily average of attendance was still increasing. The financial success of the enterprise was more than certain two months ago; and the receipts of each day since have been swelling the surplus fund, the disposal of which is now a fruitful subject of discussion in England. Although the organization is a private one, the character