provision, such as it is, not merely fails as to system and quality, but that, as to extent and quantity, "*it is far from sufficient for the vigorous prosecution of Physical Research.*"

Now, the opinions of men like these, so clearly and strongly expressed, must have carried great weight, whatever recommendations they might have founded on them; but when we consider their recommendation our faith in the soundness of their advice receives a strong accession. They do not say, as they might have done,—Establish such institutions, abolish others, alter the constitution of some, create great scientific offices, elevate the condition of scientific men, form us into a body for setting everything to rights, ourselves included. No; with an impartiality that does them honour, they say,—Place this matter before the highest tribunal known to our constitution for the deciding of such questions—before men selected for their high station and unquestionable independence; let all branches of science come in succession under their scrutiny; let the truth appear openly before the world without a possibility that an imputation of partiality and favouritism, which might attach to *our* decision, should cast a shade over their proceedings and their judgment and so damage the cause.

If we next consider the composition of the Council of the British Association, we shall feel the most positive assurance that a Report coming to them from so strong a Committee will be considered with the utmost care. For our own part we cannot feel doubtful of the result. But the question whether or not the Government shall be asked for a Royal Commission on Science is at this moment in their hands, and having said this we have brought down the history of the movement to the present moment.

A few words in conclusion. This is precisely one of those subjects which is liable to be dealt with in detail by minds before which it is definitely presented for the first time. Let us, therefore, indicate briefly the main questions, the discussion of which is, in the present stage of the matter, desirable. These are: First, does scientific investigation labour in England under disabilities and disadvantanges for want of the necessary funds and material appliances? Secondly, on what principles should the State assist scientific exertion; are these principles settled and acknowledged; and are they acted on? Thirdly, if the answers to these questions be, as we may almost assume they will be, unfavourable, is there any chance that piecemeal rectification will suffice to correct existing evils, or must we go to the root of the matter with the help of a Royal Commission?

When these questions are settled, it will be time to go more into details—but not before.

PHYSICAL METEOROLOGY

II.—SUGGESTIONS

AT the end of a previous article, I ventured to say I should make some suggestions touching a method by which I think meteorology might perhaps be made a branch of physical inquiry. In doing so, I will borrow the thought, and very many of the words which were brought before the Exeter meeting of the British Association. And furthermore, no allusion will be made in the present article to the elements of pressure and temperature.

With respect to the motion of our atmosphere, it cannot be anticipated that we shall ever possess the same complete knowledge which astronomy gives us of the motion of the heavenly bodies; for in the latter case the identity of the object is not lost sight of, while in the former case it is clearly impossible to ascertain the motions of individual particles of air. Our inquiries into the distribution and motion of the elements of our atmosphere must, therefore, be pursued by that method which enables us to ascertain the distribution and motion of any other substance or product with the individual components of which we find it impracticable to deal.

Suppose, for instance, we wish to ascertain the wealth of our country in grain or in spirits, and the distribution of this commodity over the earth's surface. We should first of all begin by taking the stock of the commodity corresponding to a given date; we should next keep a strict account of all the imports and exports of the material, as well as of its home production and home consumption.

Now, if we have taken stock properly at first, and if our account of the imports, the exports, the production, and the consumption of our material is accurate and properly kept, it will obviously be unnecessary to take stock a second time. But if these accounts are not kept with sufficient accuracy, or if we suspect that our material leaves us by some secret channel which we wish to trace, it will clearly be necessary to take stock frequently; and thus a comparison of our various accounts may enable us to detect the place and circumstances of that secret transit which has hitherto escaped our observation.

Applying these principles to the vapour of our atmosphere, what we wish to know is the amount of this material present at any one station at any moment, and also the laws of its motion. It would appear that the best way of measuring the amount present at any moment is by ascertaining the *mass* of vapour present in a *cubic foot* of air, mass and volume being fundamental physical conceptions.

Next, with regard to the motion of the atmosphere, including its vaporous constituent, the method of co-ordinates suggested by Dr. Robinson would appear to be the natural way of arriving at this. Let us set up at a station two imaginary apertures (strictly imaginary, of course), one facing north and south and the other east and west, and gauge the mass of dry air and the mass of moisture that passes each of these openings in one hour; we shall by this means get the nearest attainable approach to the elements of motion of the atmospheric constituents from hour to hour. We shall not, however, obtain by this means a complete account of this motion, for we have at present no means of measuring its vertical component. This vertical component corresponds in fact to the secret channel in the illustration given above, which we must endeavour to detect by some indirect method. Another thing that ought to be determined is the production or consumption of the vaporous element of our atmosphere as it passes from place to place. This might be done could we keep an accurate account of the evaporation and the precipitation, the two processes by which this element is recruited and consumed. This would, however, be a very difficult observation.

Let us now recapitulate what information regarding moisture we can obtain from such complete meteorological

observations as are at present made. We have to begin with, as I have shown—

(1) The mass of vapour actually present at a station from hour to hour.

(2) The mass that passes a station in one hour, going east and west.

(3) The mass that passes a station in one hour, going north and south.

There is wanting—

(4) The vertical component of the motion of vapour.

(5) Its production or consumption as it passes from place to place.

These deficiencies may, however, be to some extent overcome by the following considerations :—

First, the atmosphere moves as a whole when it moves, the dry and moist air moving together; *secondly*, dry air is neither capable of production nor of consumption, but always remains constant in amount.

To illustrate this part of the subject, let it be supposed that we wish to investigate the vertical motion of the atmosphere at a certain station. Make this station the imaginary centre of a circle, the circumference of which may be supposed to be studded with other stations at sufficiently frequent intervals, so that we can tell, hour by hour, how much dry air passes in towards the centre of the circle through its circumference, and also how much passes out.

Let us suppose that more is passing in than is passing out, or that the imports into the area of the circle are greater than the exports out of it. Now, the dry air that passes in is incapable of production or of consumption, and hence the stock of the material at the central station, and in the area generally, ought to be on the increase, since we have imagined the imports to be greater than the exports. If, however, we ascertain from actual observation that the stock of dry air is diminishing instead of increasing, we may be sure that some is carried off by an upward current, which of course carries the moisture with the dry air.

The establishment of accurate observations is so recent that I cannot at this moment produce any definite example in illustration of this mode of analysis. We may, however, take a cyclone. As I have said, there are two hypotheses with regard to the motion of air in this phenomenon : one set of philosophers advocating a strictly rotatory motion, and the other set an indraught of air from the circumference towards the centre ; and yet frequently we have a falling barometer in the centre. Now, what can carry off the air, if there be not an ascending current at the very heart of the cyclone? This is, however, I may remark, merely put forward in illustration of the method.

So much for the vertical component ; and now, in the next place, with regard to the production or consumption of aqueous vapour as it passes from place to place. Our consideration has hitherto been confined to *quantity ;* let me now define what is meant by the *hygrometric quality* of the air. It may be represented by the following quotient :—

$$\frac{\text{mass of vapour in a cubic foot}}{\text{mass of dry air in a cubic foot}}$$

Now, this quotient can only alter by evaporation, by precipitation, or by mixture. This hygrometric quality of the air may perhaps be considered a quality sufficiently constant to aid us in tracing the actual motion of air, just as we may make use of the element of saltness to trace the actual path of an oceanic current. It gives us, in fact, a chemical analysis of the air, and one, moreover, which is independent of pressure, so that we can tell by its means the various qualities of air which we meet with in a balloon or mountain ascent. But besides this aid, we may make use of it to enable us to tell the precipitation or evaporation. For instance, a very damp air, in passing over a very dry country, may be supposed to emerge less damp, having its hygrometric quality changed ; or a very dry air, in passing over a very damp country, may be supposed to emerge less dry, having its quality changed in the opposite direction. Thus, by actual observation of the quality of the air at the time of its reaching some particular tract of land or ocean, and at the time of its leaving it, we may possibly get much better observations of what goes on in the country, as far as this particular research is concerned, than if it were studded with gauges.

I would therefore suggest that meteorological observations should, by a system of reduction, be made to show—

(1) The mass of dry air and of moisture in one cubic foot actually present at each station from hour to hour.

(2) The mass of dry air and of moisture that passes each station, hour by hour, in two lines of direction at right angles to each other, namely, north and south and east and west.

When these hourly elements are obtained, they might for seasonal changes be reduced after the method of five-day means ; or for the investigation of changes of weather, they might be utilised in some other way, as, for instance, in that lately suggested by the Astronomer Royal.

I ought to remark of this method of *gauging*, that all I claim to have done is to have put it in a somewhat new form ; for it has been acted on by Maury and others before now, and has, in fact, given us one proof of the anti-trades. For we know that there is a constant indraught of air from the tropics to the equator on both sides ; and as it does not accumulate there it must be carried off somehow, that is to say, it must return by the upper regions.

Before concluding,—one word of recapitulation as to the present stage of development of meteorology. We have seen that, judging by astronomy, there ought to be three stages : the object of the first being to ascertain the actual motions of the air, the second the causes of those motions, while we prophesy in the third. We have also seen how little progress we have made in the very first of these ; and we may naturally conjecture that the third or prophetical stage is so very far in advance of us that we may not reach it for a long time. Nevertheless there is one crumb of comfort for weather prognosticators ; for just as astronomers predicted certain phenomena in a rough way before the law of gravitation was established, so here also we may make certain rough and ready predictions of much practical utility before the advent of the Newton of meteorology.

BALFOUR STEWART