subjects have been neglected, the latter has been more neglected than the former; and yet the dynamical aspect of Nature is even more important than its statical aspect.

It will be interesting at this point to consider Bacon's views about mathematics, for they exhibit his peculiar weakness and strength in a clear light. It is evident that Bacon was no mathematician. He has no theory of mathematical reasoning; he seems to be contemptuous of pure mathematics; and he was evidently unacquainted with the progress which was being made by both pure and applied mathematics in his time. It is noteworthy that in his remarks about Plato, with whom he is not altogether unsympathetic, he never thinks of Plato and his school as mathematicians but always as theologians and moralists. Yet Bacon does repeatedly say that physics cannot progress far without mathematics; and some of his strictures on the excessive worship of mathematics in science are the negative side of an important positive demand. Thus he complains that optics and astronomy have fallen wholly into the hands of mathematicians. When this complaint is investigated it is found to mean that Bacon wants something more than mere geometrical optics and mere descriptions of the courses of the heavenly bodies. He wants a *physical* optics and a *physical* atronomy, which shall deal with the *nature* of light and the *substance* of the stars and planets. His own attempts to supply this want are of very little value, but the demand is a sound one.

Although Bacon held that the proper course for scientific reasoning to take is a gradual ascent from particulars to general laws and a gradual descent from these general laws to new particulars, he was prepared to admit as a subsidiary process the direct passage from one particular to other partly analogous particulars. This he calls *Instructed Experience* (*Experientia Litterata*). He distinguishes various forms of this, of which the following are the most interesting: (1) Varying an old experiment, either by applying it to different but partly analogous materials, or by applying different but partly analogous processes to the old materials, or by varying the quantities or intensities of the factors in the old experiment. (2) Repeating the original process on the product of the previous experiment, as in redistillation. Bacon is careful to point out that we must never assume that an increase in any factor will produce a corresponding increase in the effect, or that the repetition of a process upon its product will increase the effect. (3) Extending a process from Nature to art, from one art to another, or from one part of an art to another part of it. Bacon says that new and useful processes are most likely to be discovered when one or a few men learn to compare the processes of a number of different mechanical arts. (4) Inverting one or more of the factors in an experiment; *e.g.* substituting great cold for great heat. (5) Making one factor gradually more or less intense until the characteristic effect just ceases to take place. (6) Coupling together two cause-factors, each of which has already been tried separately. Here again Bacon carefully points out that we have no right to assume that, because a in the absence of b gives α, and b in the absence of a gives β, therefore ab will give $\alpha\beta$. We may conclude this point of Bacon's doctrine with two highly characteristic quotations: "Though a successful experiment be more agreeable, an unsuccessful one is often no less instructive"; and "Experiments of Light" (*i.e.* those which throw light on the laws of Nature) "are more to be sought after than Experiments of Fruit" (*i.e.* those which lead to results that are of immediate practical use).

I will conclude by mentioning the seven cases in which the senses have to be aided and the kind of help which Bacon suggests. (1) If the object be very distant it must be joined to something which is perceptible at a distance, *e.g.* something that gives a flash or a noise. (2) If it be enclosed in an opaque envelope it must be judged by processes at the surface (*e.g.* feeling the pulse) or by what comes out from it (*e.g.* examination of urine). (3) It may be unable to affect the senses because of its intrinsic nature (*e.g.* colourless gases), or (4) because of its minuteness. The latter difficulty can be avoided by causing it to produce some effect of sensible magnitude (*e.g.* using an air-thermometer to indicate small changes of temperature). (5) Motion may be too slow or too swift to be perceived. In the former case it can be magnified by pointers and similar devices. Bacon does not know how to deal with the latter case. (6) The intensity may be too great for the senses to bear. In this case Bacon recommends the use of reflectors or semi-opaque screens. (7) The senses may be very rapidly exhausted. This happens only with taste and smell. Bacon suggests no remedy for this; but he says that where our senses fail us altogether we may use those of animals (*e.g.* dogs for scent).

Much of the merit of Bacon consists in minute detail, and is lost in a rapid sketch like the present. I think we may sum up his strength and weakness as follows. He was not a great scientist, either practically or theoretically. But he saw many of the essential factors in successful scientific procedure with great clearness, and stated them with admirable force. His method is admittedly incomplete; and no method could accomplish all that he expected of it. The nearest approach to a complete method would be a synthesis of the methods of Bacon and Descartes. But we must go far before we shall find another such combination of wide generalisation, strong common sense, balanced enthusiasm, and pointed eloquence as we find in Bacon.

The Tropical Cyclone.

By E. V. Newnham.

THE cyclone season of the northern tropics is drawing to a close. The accounts of widespread damage to property and loss of life, both in the Gulf of Mexico and in the Far East, that have appeared recently in the newspapers, show that the storms that have already occurred will make this season a memorable one. It is not intended here to deal with these recent events, but rather to present the salient facts about the tropical cyclones of both hemispheres, and to indicate the extent to which these phenomena are understood at the present time.

Like all meteorological phenomena, tropical cyclones show great individual variations from the general type; nevertheless, their general characteristics are sharply defined. In size they occupy an intermediate position between the two other kinds of atmospheric vortex that give rise to winds of hurricane strength, namely, the large cyclonic depression of temperate and high latitudes and the small but excessively violent tornado of the American and Australian type. In all three vortices the pressure of the air is greatly reduced towards the centre, but it is only in the case of the tornado that the pressure becomes too low to be recorded by the ordinary barometer.

The typical tropical cyclone consists of a nearly circular symmetrical whirl, clockwise in the southern hemisphere, counter-clockwise in the northern hemisphere, with a diameter varying from 100 to 600 miles, about a central 'eye,' where the air is nearly calm. The wind is strongest along the margin of the 'eye,' which averages about 14 miles in diameter, and in this region often greatly exceeds a hundred miles an hour. Within the 'eye' the weather is usually fair, but in the zone of strong winds torrential rains occur. The movements of the clouds are in general centrifugal, particularly as regards the higher clouds. The place of origin is in general over the hotter parts of the ocean between latitudes 8° and 12° on both sides of the equator, generally near the equatorial margin of the trade winds bordering the doldrums, or belt of equatorial calms and light winds, but in the case of the storms in the Bay of Bengal and the Arabian Sea, in the region of variable winds and squalls that occur at the transitions between the north-east monsoon of the winter and the south-west monsoon of the summer.

Tropical cyclones form in three zones:

(1) The south-western part of the North Atlantic, around the West Indies.

(2) From the Arabian Sea eastwards so far as the China Seas and western part of the North Pacific.

(3) From around Madagascar eastwards to the Paumotu Islands.

There is, as a rule, one definite season extending over several months and reaching a maximum a little before the autumn equinox, when the ocean is generally at its warmest. Individual seasons differ greatly as regards the number and intensity of the storms that occur, and a connexion has been claimed by some writers between the character of the season and the number and size of the spots on the sun, but a clear relationship for the whole area affected by cyclones has not been established so far.

Cyclones move slowly along paths which also show great variation, but a dominant tendency towards motion along a certain type of curved path, sometimes described as parabolic or hyperbolic, is apparent in all parts of the world where a large mass of land is not so situated as to prevent the storm from passing through its normal life-history.[1] The motion during the first few days is compounded of an east to west drift, and a slight poleward drift, but somewhere between latitudes 20° and 30° (north or south) the motion becomes directly poleward and then inclines towards the east, becoming north-easterly on leaving the northern tropics and south-easterly on leaving the southern tropics. It should be noted that within the tropics the movement is clearly not in accordance with the prevailing winds of the region through which the storm is passing, and is more often than not almost directly opposed to those winds,[2] but on leaving the tropics, when the storm begins to lose its tropical characteristics and take on those of the ordinary temperate 'depression,' the motion, in the case of the cyclones of the North Atlantic and the China Seas, appears as a rule to be that of the prevailing winds, between about latitudes 30° and 50° N.

To return to the important subject of their place and time of origin: whatever the process may be whereby a cyclone begins to form in a region of light and variable winds, there can be little doubt that their whirling motion is due to the deflective force of the earth's rotation. Now this force varies as the sine of the latitude, and is therefore inappreciable for some degrees north and south of the equator; this fact explains why cyclones seldom originate within 8° of the equator. The reason why the time of maximum frequency is normally just before the autumn equinox appears to be that one of the necessary conditions for the formation of a cyclone is a discontinuity between distinct wind systems, and this will be found at a suitable distance from the equator when the equatorial belt of calms (the doldrums) is nearly at its farthest from the equator, *i.e.* not long after the summer solstice, the maximum being retarded somewhat because the greatest warmth of the ocean is normally attained about two months after the solstice. In the case of the Indian cyclones there is a double maximum, one in early summer and the other in autumn; in this case, the controlling factor is clearly the presence or absence of the necessary discontinuity of wind, the warmth of the sea appearing to play little part in fixing the cyclone season.

The above general description of tropical cyclones is based mainly upon a recent memoir of the British Meteorological Office,[3] which is in turn based upon all available contributions to the literature of the subject up to 1920. In the introduction to this work, Sir Napier Shaw attempts to explain the life-history of a tropical cyclone from its birth, as a result of the convection in suitable circumstances of hot moist air, to its death, when, having been transformed into a cyclonic depression of temperate latitudes, it is surrounded by cold dry air on reaching the polar regions. The convectional stage is developed in a very ingenious manner; a number of small convectional 'bubbles' are assumed to unite into a single large 'bubble'; air is withdrawn over a certain area and is 'evicted' in the upper atmosphere; the system quickly acquires the properties of a fully developed cyclone and begins to drift towards the west. In a theoretical section, Dr. H. Jeffreys, regards a combination of the two principal theories so far advanced to explain the origin of cyclones—the 'millpond eddy' and the

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[1] The storms of the Bay of Bengal and Arabian Sea appear to behave normally in this respect, but the great land mass to the north does not allow them to survive long enough to follow more than the first third or half of the typical path.

[2] So far as I am aware, this point has not been emphasised hitherto. Its truth rests upon the accuracy of the charts of prevailing wind published in "Bartholomew's Physical Atlas," vol. 3, plate 14, which are due mainly to Köppen.

[3] "Hurricanes and Tropical Revolving Storms." By Mrs. E. V. Newnham. Meteorological Office Memoir, No. 19, 1922.

'convectional' theories—as necessary for a complete explanation.

Since 1920 several further contributions have been made to the literature of tropical cyclones. One deals with the region around the West Indies.[4] Redrawing the tracks of all known cyclones in this area since 1886, Mitchell found that no storm originated over the eastern two-thirds of the Caribbean Sea; many storms originated, however, south of the Cape Verde Islands, and some over the western third of the Caribbean Sea. The deciding factor in this case, as for the Indian cyclones, appears to be the presence or absence of a discontinuity between conflicting winds; such a discontinuity is absent over the eastern two-thirds of the Caribbean Sea. Another interesting fact pointed out by Mitchell is that the cyclone of this area 'recurves' (*i.e.* turns directly polewards) as soon as a trough of low pressure arrives to the north, irrespective of the longitude and time of year.

Another recent valuable publication deals statistically with the tropical cyclones of Australia, without, however, contributing much that is new to the theory of the storms.[5] The last paper to which I shall refer is concerned with the dynamics of the formation of cyclones.[6] Capt. Brunt follows Shaw in regarding simple thermal convection of moist air as the initial stage, the energy for the subsequent violent winds being supplied by the latent heat of condensation of the water vapour that is precipitated in the rising column of air before those winds arise. He lays stress on the importance of explaining how the removal of air from the centre of a developing storm is brought about, and presumes that it is effected by the discharge of the column of rising air into strong upper winds.

The verification or refutation of this and of the various alternative theories of the origin of cyclones that have been brought forward, which space does not permit me to describe, awaits a more complete knowledge of the temperature, humidity, and wind at all levels in the regions of formation of cyclones, which are unfortunately in most cases just where observations of any kind are most difficult to obtain.

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[4] "West Indian Hurricanes and other Tropical Cyclones of the North Atlantic Ocean." By C. L. Mitchell. *Monthly Weather Review.* Supplement No. 24, 1924.

[5] "Australian Hurricanes and Related Storms." By S. Visher and D. Hodge, 1925.

[6] "The Origin of Tropical Revolving Storms." By D. Brunt, London Meteorological Office. *Marine Observer*, 1924.

The Reported Conversion of Hydrogen into Helium.

THE current (September) issue of the *Berichte* of the German Chemical Society contains a paper by Profs. F. Paneth and K. Peters on "The Transformation of Hydrogen into Helium," in which they describe in outline how they have succeeded in detecting the presence of very minute amounts of helium, of the order of one hundred millionth of a cubic centimetre, derived from hydrogen which had been absorbed by finely divided palladium at the ordinary temperature.

Theory indicating that this conversion would involve the liberation of much energy ($6{\cdot}4 \times 10^{11}$ cal. from 4 gram-atoms of hydrogen), the author's primary task was to find out if the change would take place without introducing energy from outside, *e.g.* in the presence of a catalyst; and in order to be able to detect very small quantities of helium they elaborated the spectroscopic method in such a way that the limiting amount detectable was 10^{-8}-10^{-9} c.c., or 10^{-12}-10^{-13} gm. Easily liquefiable gas was removed with liquid air and charcoal; oxygen was added and the hydrogen burnt on the surface of the catalyst; water-vapour and excess oxygen were removed with charcoal, and the residual gas was passed into a glass capillary-tube of 0·1 mm. section, which was surrounded with electrode-wires and placed before the slit of the spectroscope. Every precaution was taken to exclude atmospheric helium; the portion of the apparatus that was heated was surrounded with a vacuum-mantle and immersed in water. The presence of neon lines afforded a most valuable criterion of the presence of atmospheric gases; neon was never completely excluded, but the amount present was so small that it did not invalidate the author's main conclusion.

The method is so delicate that the liberation of helium from a mixture of thorium B and thorium C was easily detected, while it is sufficiently sensitive to determine the presence of helium in a few cubic centimetres of natural gas. By its means a natural gas containing 0·19 per cent. by volume of helium was discovered in Germany, and steps have been taken to exploit it commercially. The Canadian natural gas from which helium is extracted contains 0·33 per cent. by volume.

Attempts were made to effect the transformation by submitting hydrogen to the action of a silent electric discharge in an ozone apparatus, and by passing a prolonged and powerful discharge through it in a Geissler-tube fitted with aluminium electrodes; but no success was achieved. Nor was the attempt to produce helium by bombarding certain salts with cathode rays, as suggested by Lord Rayleigh, any more fertile, so that recourse was had to passing fairly large amounts of hydrogen—up to one litre—through heated palladium, in the hope that at the moment of exit a fraction of the protons and electrons would combine to form the helium nucleus. In this case the indications were favourable, but the result was inconclusive owing to the presence of atmospheric neon, and the absence of any proportionality between the strength of the helium lines and the amount of hydrogen that was used.

Finely-divided palladium, either as sponge, 'black,' or palladinised asbestos, was then used to absorb hydrogen at room temperature, and after different intervals of time the hydrogen was combined with oxygen, as previously described. The residual gas obtained after a 12-hours' contact between palladium and hydrogen exhibited four or five lines of the helium spectrum and only a single neon-line; there was also a distinct proportionality between the amount of helium observed and the duration of the time of contact. The activity of the different palladium preparations employed varied considerably; it invariably diminished with repeated use, but both the power of absorbing hydrogen and of effecting the transformation were restored by heating in hydrogen or oxygen, in a mixture