referrea to, but which may be otnerwise thus put :—Stand with your back to the wind, and the lowest barometer, or centre of depression, will be to your left in the northern hemisphere (in the southern hemisphere to the right); this rule holds universally. (2.) The *force* of the wind is proportional to the barometric gradient, or the quotient of the distance between two places stated in miles by the difference of pressure stated in inches of mercury as observed at the two places. Hence, in the Channel, where the isobarics are close together, winds are high, but in the north of Scotland, where the isobarics are far apart, winds are light. This rule also holds universally, though the exact relation requires still to be worked out by observation. As regards the important climatic elements of temperature and moisture, the air in the S.S.E. half of the cyclone is mild and humid, and much rain falls; but in the other half it is cold and dry, and little rain falls. A succession of low pressures passing eastward, in a course lying to northwards of Great Britain, is the characteristic of an open winter in Great Britain; on the other hand, if the cyclones follow a course lying to the southward, the winters are severe. This is a chief point of climatic importance connected with the propagation eastward of these cyclonic areas.

FIG. 1.—Weather chart, showing cyclone.

2. *Areas of High Pressures, or Anticyclones*—The accompanying weather chart, fig. 2, for 2–4th August 1868, represents an anticyclone or region of high pressure, which overspread the greater part of Europe at that time. Here the highest pressure is in the centre of the system, and, as usually happens, the isobarics are less symmetrical than those near the centre of a cyclone. The winds, as usual in anticyclones, are light; this, however, is the essential point of difference—the winds do not flow inwards upon the centre, but outwards from the region of high pressure; and it will be observed that in many cases they cut the isobarics at nearly right angles. Another important point of difference is in the air over the region covered by the anticyclone being, particularly in its central portion, very dry, and either clear or nearly free from clouds.

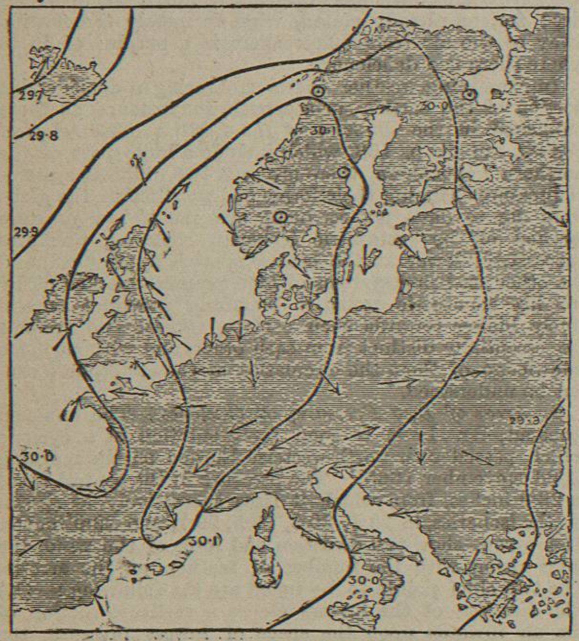

FIG. 2.—Weather chart, showing anticyclone.

Climatically, the significance of the anticyclone consists in the space covered for the time by it being, on account of its dryness and clearness, more fully under the influence of both solar and terrestrial radiation; and consequently in winter it is accompanied with great cold, and in summer with great heat. As shown by Buchan, in reviewing the weather of north-western Europe for 1868,[1] the intense heat which prevailed in Great Britain during 2–4th August of that year was due to the high barometric pressure accompanying this anticyclone, the comparative calmness of the atmosphere, the clearness of the sky, the dryness of the air, and the strong insolation which took place under these circumstances.

Thus, then, the tendency of the winds on the surface of the earth is to blow round and in upon the space where pressures are low and out of the space where pressures are high. Now, since vast volumes of air are in this way poured into the space where pressure is low, without increasing that pressure, and, on the other hand, vast volumes flow out of the space where pressure is high, without diminishing that pressure, it necessarily follows that the air poured in is not allowed to accumulate over this space, but must escape into other regions; and also that the air which flows out from the anticyclonic region must have its place supplied by fresh accessions from above. In other words, the central space of the cyclone is occupied by a vast ascending current, which after rising to a considerable height flows away as upper currents into surrounding regions; and the central space of the anticyclone is filled by a slowly descending current, which is fed from upper currents, blowing towards it from neighbouring regions. When the area of observation is made sufficiently wide, cyclones are seen to have one, or sometimes more, anticyclones in proximity to them, the better marked anticyclones having two, and sometimes more, cyclones in their vicinity. In fig. 2, a part of a cyclone in Iceland is seen, and another cyclone in the Crimea accompanied the anticyclone there figured. Hence the cyclone and the anticyclone are properly to be regarded as counterparts, belonging to one and the same great atmospheric disturbance.

From this it follows that observations of the winds cannot be conducted, and the results discussed, on the supposition that the general movement of the winds felt on the earth's surface is horizontal, it being evident that the circulation of the atmosphere is effected largely through systems of ascending and descending currents. The only satisfactory way of discussing the winds, viewed especially in their climatic relations, is that recently proposed by Köppen of St Petersburg, and applied by him with very fruitful results in investigating the weather of that place during 1872 and 1873. In attempting an explanation of these phenomena, we are met with several as yet insuperable obstacles :—(1.) An imperfect knowledge of the mode of formation and propagation of low-pressure systems; (2.) Imperfect knowledge of the relations of the formation of cloud and aqueous precipitation to barometric fluctuations; (3.) A want of information with reference to the merely mechanical effects of ascending, descending, and horizontal currents of air on the barometric pressure; in other words, we do not know how far the barometric pressure is an indication of the mass of air in the column vertically over it, when that column is traversed by air-currents; (4.) An almost total absence of really good wind observations; and (5.) Deficient information in nearly everything that respects aqueous vapour—its relation to radiant heat, both solar and terrestrial; its mode of diffusion vertically and horizontally in the free atmosphere, especially from an evaporating surface; the influence which its condensation into cloud and rain exerts on aerial currents,—in regard to all which more satisfactory methods of observing this vital element, and discussing the results of observation, are greatly to be desired. There are here large important fields of inquiry awaiting experimental and observational physicists.

[1] *Atlas Météorologique de l'Observatoire Impérial*, Année 1868, p. 39.

The law of the dilatation of gases, known as the "Law of Boyle" or "Law of Mariotte," is this: The volume occupied by a gas is in inverse ratio to the pressure under which it exists, if the temperature remains the same; or the density of a gas is proportioned to its pressure. Consequently, air under a pressure equal to that of two atmospheres will occupy only half the volume it occupied under the pressure of one atmosphere; under the pressure of three atmospheres, one-third of that volume, &c. By doubling the pressure we double the elasticity. If, however, the temperature be increased, and the air occupy the same space, the pressure will be increased; but if the pressure is to remain the same, the air must occupy a larger space. From Regnault's experiments, it is concluded that the co-efficient which denotes increase of elasticity for 1° Fahr. of air whose volume is constant equals ·002036; and that the co-efficient which denotes increase of volume for 1° Fahr. of air whose elasticity is constant equals ·002039.

Those portions of the atmosphere in contact with the earth are pressed upon by all the air above them. The air at the top of a mountain is pressed upon by all the air above it, while all the portion below it, or lying between the top of the mountain and the surface of the sea, exerts no pressure whatever upon it. Thus the pressure of the atmosphere constantly diminishes with the height. If, then, the pressure of the atmosphere at two heights be observed, and if at the same time the mean temperature and humidity of the whole stratum of air lying between the two levels were known, the difference in height between the two places could be calculated. For the development of this principle, see BAROMETRIC MEASUREMENTS OF HEIGHTS.

The air thus diminishing in density as we ascend, if it consists of ultimate atoms, as is no doubt the case, it follows that the limit of the atmosphere will be reached at the height where the force of gravity downwards upon a single particle is equal to the resisting force arising from the repulsive force of the particles. It was long supposed, from the results of observations on the refraction of light, that the height of the atmosphere did not exceed 45 miles; but from the observations of luminous meteors, whose true character as cosmical bodies was established a few years ago, it is inferred that the height of the atmosphere is at least 120 miles, and that, in an extremely attenuated form, it may even reach 200 miles.

Though there are considerable differences in the specific gravities of the four constituent gases of the atmosphere, viz., oxygen, nitrogen, carbonic acid gas, and aqueous vapour, there is yet no tendency to separation among them, owing to the law of diffusion obtaining among elastic fluids mixed together. While the proportion of these gases is in a general sense constant, there are, however, consistent differences in the amounts of oxygen and nitrogen in the air of unwholesome places, as first shown by Regnault. The following figures, showing the volume per cent. of oxygen, rest on the authority of Dr Angus Smith, who has given much attention to this subject :—Sea-shore of Scotland and Atlantic (lat. 43° 5′ N., long. 17° 12′ W.), 20·99; tops of Scottish hills, 20·98; in sitting-room feeling close but not excessively so, 20·89; backs of houses and closets, 20·70; under shafts in metalliferous mines, 20·424; when candles go out, 18·50; when it is very difficult to remain in the air many minutes, 17·20. The variations in the amounts of carbonic acid in different situations are great; thus—in the London parks it is ·0301; on the Thames, ·0343; where fields begin, ·0369; in London streets in summer, ·0380; during fogs in Manchester, ·0679; in workshops it rises to ·3000, and in the worst parts of theatres to ·3200; and the largest amount, found in Cornwall mines, is 2·5000.

Great differences have been observed by Dr A. Smith between country rain and town rain: country rain is neutral; town rain, on the other hand, is acid, and corrodes metals and even stones and bricks, destroying mortar rapidly, and readily spoiling many colours. Much information has been obtained regarding impurities in the air of towns and other places by examining the rain collected in different places. The air freest from impurities is that collected at the sea-coast and at considerable heights. Again, ammonia is found to diminish, while nitric acid increases, in ascending to, at least, habitable heights. As regards organic matter in the air, it corresponds to a considerable extent with the density of the population. As might have been supposed from the higher temperature, more nitric acid is contained in rain collected on the Continent than in the British Islands. This inquiry, which is only yet in its infancy, will doubtless continue to be vigorously prosecuted, particularly since we may hope thereby to arrive at the means of authoritatively defining the safe limits of the density of population, and the extent to which manufactures may be carried on within a given area. The influence of atmospheric impurities on the public health has received a good deal of attention.

The relation of weather to mortality is a very important inquiry, and though a good deal has been known regarding the question for some time, yet it has only recently been systematically inquired into by Dr Arthur Mitchell and Mr Buchan, the results of the investigation which deals with the mortality of London being published in the *Journal of the Scottish Meteorological Society* (New Series, Nos. 43 to 46). Considering the weather of the year as made up of several distinct climates differing from each other according to temperature and moisture and their relations to each other, it may be divided into six distinct climates, characterised respectively by cold, cold with dryness, dryness with heat, heat, heat with moisture, and cold with moisture. Each of these six periods has a peculiar influence in increasing or diminishing the mortality, and each has its own group of diseases which rise to the maximum, or fall to the minimum mortality, or are subject to a rapid increase or a rapid decrease. The mortality from all causes and at all ages shows a large excess above the average from the middle of November to the middle of April, from which it falls to the minimum in the end of May; it then slowly rises, and on the third week of July suddenly shoots up almost as high as the winter maximum of the year, at which it remains till the second week of August, falling thence as rapidly as it rose to a secondary minimum in October. Regarding the summer excess, which is so abrupt in its rise and fall, it is almost altogether due to the enormous increase of the mortality among mere infants under one year of age; and this increase is due not only to deaths at one age, but to deaths from one class of diseases, viz., bowel complaints. If the deaths from bowel complaints be deducted from the deaths from all causes, there remains an excess of deaths in the cold months, and a deficiency in the warm months. In other words, the curve of mortality is regulated by the large number of deaths from diseases of the respiratory organs. The curve of mortality for London, if mere infants be excepted, has thus an inverse relation to the temperature, rising as the temperature falls, and falling as the temperature rises. On the other hand, in Victoria, Australia, where the summers are hotter and the winters milder, the curves of mortality and temperature are directly related to each other—mortality and temperature rising and falling together; the reason being that in Victoria deaths from bowel complaints are much greater, and those from diseases of the respiratory organs much less than in London.

The curves show that the maximum annual mortality from the different diseases groups around certain specific conditions of temperature and moisture combined. Thus, *cold and moist weather* is accompanied with a high death-rate from rheumatism, heart diseases, diphtheria, and measles; *cold weather*, with a high death-rate from bronchitis, pneumonia, &c.; *cold and dry weather*, with a high death-rate from brain diseases, whooping-cough, convulsions; *warm and dry weather*, with a high death-rate from suicide and small-pox; *hot weather*, with a high death-rate from bowel complaints; and *warm moist weather* with a high death-rate from scarlet and typhoid fevers. (See CLIMATE.) B.)

ATMOSPHERIC RAILWAY, a railway in which the pressure of air is used directly or indirectly to propel carriages, as a substitute for steam. It was devised at a time when the principles of propulsion were not so well understood as they are now, and when the dangers and inconveniences attendant on the use of locomotives were very much exaggerated. It had been long known that small objects could be propelled for great distances through tubes by air pressure, but a Mr Vallance, of Brighton, seems to have been the first to propose the application of this system to passenger traffic. He projected (about 1825) an atmospheric railway, consisting of a wooden tube about 6 feet 6 inches in diameter, with a carriage running inside it. A diaphragm fitting the tube, approximately air-tight, was attached to the carriage, and the air exhausted from the front of it by a stationary engine, so that the atmospheric pressure behind drove the carriage forward. Later inventors, commencing with Henry Pinkus (1835), for the most part kept the carriages altogether outside the tube, and connected them by a bar with a piston working inside it, this piston being moved by atmospheric pressure in the way just mentioned. The tube was generally provided with a slot upon its upper side, closed by a continuous valve or its equivalent, and arrangements were made by which this valve should be opened to allow the passage of the driving bar without permitting great leakage of air. About 1840, Messrs Clegg & Samuda made various experiments with an atmospheric tube constructed on this principle upon a portion of the West London Railway, near Wormwood Scrubs. The apparent success of these induced the Dublin and Kingstown Railway to adopt Clegg & Samuda's scheme upon an extension of their line from Kingstown to Dalkey, where it was in operation in 1844. Later on, the same system was adopted on a part of the South Devon line and in several other places, and during the years 1844–1846 the English and French patent records show a very large number of more or less practicable and ingenious schemes for the tubes, valves, and driving gear of atmospheric railways. The atmospheric system was nowhere permanently successful, but in all cases was eventually superseded by locomotives, the last atmospheric line being probably that at St Germains, which was worked until 1862. Apart from difficulties in connection with the working of the valve, the maintenance of the vacuum, &c., other great practical difficulties, which had not been indicated by the experiments, soon made themselves known in the working of the lines. Above all, it was found that stationary engines, whether hauling a rope or exhausting a tube, could never work a railway with anything like the economy or the convenience of locomotives, a point which is now regarded as settled by engineers, but which was not so thoroughly understood thirty years ago. Lately, the principle of the atmospheric railway has been applied on a very large scale in London and elsewhere, under the name of "PNEUMATIC DESPATCH" (*q.v.*), to the transmission of small parcels in connection with postal and telegraph work, for which purpose it has proved admirably adapted. (See paper by Prof. Sternberg of Carlsruhe in Hensinger von Waldegg's *Handbuch für specielle Eisenbahntechnik*, vol. i. pt. 2, cap. xvii.

ATOM

ATOM (ἄτομος) is a body which cannot be cut in two. The atomic theory is a theory of the constitution of bodies, which asserts that they are made up of atoms. The opposite theory is that of the homogeneity and continuity of bodies, and asserts, at least in the case of bodies having no apparent organisation, such, for instance, as water, that as we can divide a drop of water into two parts which are each of them drops of water, so we have reason to believe that these smaller drops can be divided again, and the theory goes on to assert that there is nothing in the nature of things to hinder this process of division from being repeated over and over again, times without end. This is the doctrine of the infinite divisibility of bodies, and it is in direct contradiction with the theory of atoms.

The atomists assert that after a certain number of such divisions the parts would be no longer divisible, because each of them would be an atom. The advocates of the continuity of matter assert that the smallest conceivable body has parts, and that whatever has parts may be divided.

In ancient times Democritus was the founder of the atomic theory, while Anaxagoras propounded that of continuity, under the name of the doctrine of homœomeria (Ὁμοιομέρια), or of the similarity of the parts of a body to the whole. The arguments of the atomists, and their replies to the objections of Anaxagoras, are to be found in Lucretius.

In modern times the study of nature has brought to light many properties of bodies which appear to depend on the magnitude and motions of their ultimate constituents, and the question of the existence of atoms has once more become conspicuous among scientific inquiries.

We shall begin by stating the opposing doctrines of atoms and of continuity before giving an outline of the state of molecular science as it now exists. In the earliest times the most ancient philosophers whose speculations are known to us seem to have discussed the ideas of number and of continuous magnitude, of space and time, of matter and motion, with a native power of thought which has probably never been surpassed. Their actual knowledge, however, and their scientific experience were necessarily limited, because in their days the records of human thought were only beginning to accumulate. It is probable that the first exact notions of quantity were founded on the consideration of number. It is by the help of numbers that concrete quantities are practically measured and calculated. Now, number is discontinuous. We pass from one number to the next *per saltum*. The magnitudes, on the other hand, which we meet with in geometry, are essentially continuous. The attempt to apply numerical methods to the comparison of geometrical quantities led to the doctrine of incommensurables, and to that of the infinite divisibility of space. Meanwhile, the same considerations had not been applied to time, so that in the days of Zeno of Elea time was still regarded as made up of a finite number of "moments," while space was confessed to be divisible without limit. This was the state of opinion when the celebrated arguments against the possibility of motion, of which that of Achilles and the tortoise is a specimen, were propounded by Zeno, and such, apparently, continued to be the state of opinion till Aristotle pointed out that time is divisible without limit, in precisely the same sense that space is. And the slowness of the development of scientific ideas may be estimated from the fact that Bayle does not see any force in this statement of Aristotle, but continues to admire the paradox of Zeno. (Bayle's *Dictionary*, art. "Zeno"). Thus the direction of true scientific progress was for many ages towards the recognition of the infinite divisibility of space and time.

It was easy to attempt to apply similar arguments to matter. If matter is extended and fills space, the same mental operation by which we recognise the divisibility of space may be applied, in imagination at least, to the matter which occupies space. From this point of view the atomic doctrine might be regarded as a relic of the old numerical way of conceiving magnitude, and the opposite doctrine of the infinite divisibility of matter might appear for a time the most scientific. The atomists, on the other hand, asserted very strongly the distinction between matter and space. The atoms, they said, do not fill up the universe; there are void spaces between them. If it were not so, Lucretius tells us, there could be no motion, for the atom which gives way first must have some empty place to move into.

> "Quapropter locus est intactus, inane, vacansque
> Quod si non esset, nulla ratione moveri
> Res possent; namque, officium quod corporis exstat,
> Officere atque obstare, id in omni tempore adesset
> Omnibus: haud igitur quicquam procedere posset,
> Principium quoniam cedendi nulla daret res."
> *De Rerum Natura*, i. 335.

The opposite school maintained then, as they have always done, that there is no vacuum—that every part of space is full of matter, that there is a universal plenum, and that all motion is like that of a fish in the water, which yields in front of the fish because the fish leaves room for it behind.

> "Cedere squamigeris latices nitentibus aiunt
> Et liquidas aperire vias, quia post loca pisces
> Linquant, quo possint cedentes confluere undæ."
> —i. 373.

In modern times Descartes held that, as it is of the essence of matter to be extended in length, breadth, and thickness, so it is of the essence of extension to be occupied by matter, for extension cannot be an extension of nothing.

> "Ac proinde si quæratur quid fiet, si Deus auferat omne corpus quod in aliquo vase continetur, et nullum aliud in ablati locum venire permittat? respondendum est, vasis latera sibi invicem hoc ipso fore contigua. Cum enim inter duo corpora nihil interjacet, necesse est ut se mutuo tangant, ac manifeste repugnat ut distent, sive ut inter ipsa sit distantia, et tamen ut ista distantia sit nihil; quia omnis distantia est modus extensionis, et ideo sine substantia extensa esse non potest."—*Principia*, ii. 18.

This identification of extension with substance runs through the whole of Descartes's works, and it forms one of the ultimate foundations of the system of Spinoza. Descartes, consistently with this doctrine, denied the existence of atoms as parts of matter, which by their own nature are indivisible. He seems to admit, however, that the Deity might make certain particles of matter indivisible in this sense, that no creature should be able to divide them. These particles, however, would be still divisible by their own nature, because the Deity cannot diminish his own power, and therefore must retain his power of dividing them. Leibnitz, on the other hand, regarded his monad as the ultimate element of everything.

There are thus two modes of thinking about the constitution of bodies, which have had their adherents both in ancient and in modern times. They correspond to the two methods of regarding quantity—the arithmetical and the geometrical. To the atomist the true method of estimating the quantity of matter in a body is to count the atoms in it. The void spaces between the atoms count for nothing. To those who identify matter with extension, the volume of space occupied by a body is the only measure of the quantity of matter in it.

Of the different forms of the atomic theory, that of Boscovich may be taken as an example of the purest monadism. According to Boscovich matter is made up of atoms. Each atom is an indivisible point, having position in space, capable of motion in a continuous path, and possessing a certain mass, whereby a certain amount of force is required to produce a given change of motion. Besides this the atom is endowed with potential force, that is to say, that any two atoms attract or repel each other with a force depending on their distance apart. The law of this force, for all distances greater than say the thousandth of an inch, is an attraction varying as the inverse square of the distance. For smaller distances the force is an attraction for one distance and a repulsion for another, according to some law not yet discovered. Boscovich himself, in order to obviate the possibility of two atoms ever being in the same place, asserts that the ultimate force is a repulsion which increases without limit as the distance diminishes without limit, so that two atoms can never coincide. But this seems an unwarrantable concession to the vulgar opinion that two bodies cannot co-exist in the same place. This opinion is deduced from our experience of the behaviour of bodies of sensible size, but we have no experimental evidence that two atoms may not sometimes coincide. For instance, if oxygen and hydrogen combine to form water, we have no experimental evidence that the molecule of oxygen is not in the very same place with the two molecules of hydrogen. Many persons cannot get rid of the opinion that all matter is extended in length, breadth, and depth. This is a prejudice of the same kind with the last, arising from our experience of bodies consisting of immense multitudes of atoms. The system of atoms, according to Boscovich, occupies a certain region of space in virtue of the forces acting between the component atoms of the system and any other atoms when brought near them. No other system of atoms can occupy the same region of space at the same time, because, before it could do so, the mutual