Physiologists have taught all the 40,000 medical men in Great Britain. These practitioners of medicine are busy with their own technical art, and that is neither physiology nor clinical science, though it is inspired by each. Year by year their work grows more effective, thanks to progress in scientific knowledge of disease. Lord Nuffield's

gift will augment the number of those aiding this advance by work in clinical science, and still leave them few in comparison with those in the other medical sciences whose work is less directly related, and therefore less immediately applicable, to the treatment and prevention of disease.

Chemical Exploration of the Stratosphere*

By Prof. F. A. Paneth

STUDENTS of the history of astronomy may remember that those of the natural philosophers in old Greece who favoured a geocentric conception pictured the universe as being built up of several spheres surrounding the earth. According to Aristotle, the sub-lunar world consisted of the four elements, each tending to its "natural place"; innermost was the core of the earth, surrounded by layers, first of water, then of air, and fire, wherever found, trying to rise to the top layer. Next came the realm of the "quinta essentia", the substance of the celestial bodies; but these were not supposed to circle in one and the same sphere. In order to explain the movements of the planets, Aristotle saw himself compelled to assume not less than fifty-six spheres in the sky, all concentric with the earth.

It looks somewhat like a revival of these old ideas that to-day science speaks of many concentric layers in the earth, sea and atmosphere. Since the development of modern seismology and geochemistry, it is known that the earth consists of at least four regions: a core of liquid iron in the centre, then a medium shell of, probably, sulphidic ores, covered by two outer shells of rocks of different densities. Fairly recently, in the early part of this century, it was discovered by Teisserenc de Bort that the thermal qualities of the atmosphere show a break when the height of about 11 km. (in our latitudes) is attained. In the lower part, called the 'troposphere', the temperature decreases regularly with increasing altitude until, at the height mentioned, about -53°C . is reached. From here onwards, however, the temperature remains nearly constant at any height accessible to direct meteorological measurements. We have obviously entered a layer of the atmosphere in which different physical conditions prevail: the 'stratosphere'.

For a while it was assumed that the constant temperature of the stratosphere might extend to

the top of the atmosphere. But from 1922 onwards it became clear that the structure of the atmosphere is much more complicated. We now know from indirect evidence, interpreted by Lindemann, Dobson and Whipple, that in regions at present beyond the reach of any thermometer, between 30 km. and 40 km., the temperature of the atmosphere begins markedly to increase again, and that this warmer layer is responsible for the reflection of sound waves; that at about 100 km. and again at 300 km. there exist strata of ionized air which play a role in the reflection of radio waves (Kennelly-Heaviside and Appleton layers); and that in the highest parts of the atmosphere a gaseous mass of about $1,000^{\circ}\text{C}$. is to be assumed. However complicated this may sound (even if we add that oceanographers nowadays distinguish between a 'troposphere', the upper layer of the sea in which the temperature decreases with descent, and a 'stratosphere' of fairly constant temperature below) we may still console ourselves by the thought that the modern scientific picture of the onion-like structure of the earth, sea and air is yet much less involved than the speculation of the ancient philosophers, and that its exploration advances quickly, thanks to the co-operation of various sciences.

While the temperature and the electrical state of the stratosphere have been the subject of many investigations, its chemical composition has seldom been studied. But so early as 1912, Tetens pointed out that a chemical investigation of the composition of the stratosphere would be the best, if not the only, means of deciding the question raised right at the beginning by the discovery of the stratosphere: Does the constancy of temperature mean that there is no convective motion of air masses; does it prove the absence of winds?

It is not difficult to see why the chemist should be able to settle this question. If it were possible in a long vertical tube containing a homogeneous

* From the Friday Evening Discourse at the Royal Institution delivered on November 6.

mixture of two gases of different densities to prevent every disturbance from outside, then we should expect the relative proportion of the gases no longer to remain constant throughout the length of the tube, but the heavier gas to concentrate near the bottom, the lighter near the top. This is a consequence of Dalton's law, which states that the variation with height of the density of each gas is the same as if it alone were present. The conclusion has never been experimentally verified, as it is scarcely possible to keep vertical gas columns of sufficient lengths—100 m. would be a good start—free from all disturbances. Only as a historical curiosity it may be mentioned that in the classical book on acoustics by Chladni (1802), an experiment is quoted by a Vienna professor who succeeded in separating the nitrogen and oxygen of atmospheric air in a vertical tube of not more than five feet length, simply by leaving it alone for one year!

Fig. 1.

DISTRIBUTION UNDER GRAVITY OF PARTICLES OF DIFFERENT DENSITIES SUSPENDED IN WATER.

Thanks to the great development of the kinetic theory of gases we can, however, predict in every detail what is bound to happen in long vertical columns; and on a reduced scale it is possible to test the conclusions in a model experiment. Einstein was the first to point out that little particles suspended in water are subject to the same two conflicting tendencies as the molecules of a gas; on one hand they try to settle down, due to the force of gravity; on the other, their tendency to diffuse drives them asunder in all directions, including the one opposed to gravitation. As a result their equilibrium distribution must follow the same well-known 'barometric altimetry formula' for the decrease of concentration with height as does atmospheric air; with the one difference that,

owing to the enormous contrast between the weight of visible particles and that of gas molecules, the phenomenon of thinning out with height must become perceptible at much smaller distances. The density of oxygen, for example, decreases to half its original value if we ascend to a height of about 5,000 m.; in a suspension of microscopic particles in water, the concentration should fall to half the initial value within a minute fraction of a millimetre, the rate of decrease depending, amongst other factors, on the specific weight of the particles.

Einstein's predictions have been tested experimentally by the French physicist Perrin and others. Fig. 1 illustrates on an enlarged scale what has actually been seen under the microscope. Each of the three suspensions, of heavy, medium and light particles, shows the regular decrease of concentration with height, following the barometric formula; but the one with the heaviest particles displays the phenomenon within the shortest range. If we mix the three emulsions by stirring, the particles will at first be homogeneously distributed throughout the whole column of water; but as soon as we leave them undisturbed—that means subjected no longer to large-scale mixing, but only to the forces of diffusion and gravitation—the height distribution peculiar to each of them will be restored, and so the percentage concentration of the heavier particles will increase near the bottom, of the lighter particles near the top.

Let us apply this knowledge to the atmosphere. It consists of a complicated mixture of gases.

TABLE 1.
COMPOSITION OF THE TROPOSPHERE (PER CENT BY VOLUME).

Nitrogen	78.08	} 99.99
Oxygen	20.95	
Argon	0.93	
Carbon dioxide	0.03	
Neon	1.8×10^{-3}	
Helium	5×10^{-4}	
Krypton	1×10^{-4}	
Xenon	1×10^{-5}	
Ozone	variable; $> 1 \times 10^{-6}$	
Radon (average near ground)	6×10^{-10}	
Hydrogen	doubtful; $< 1 \times 10^{-4}$	

In Table 1 the composition of atmospheric air is given. The content of water vapour, as is well known, is so variable that I have omitted it entirely; the table refers to dry air. The carbon dioxide, ozone and radon content, for different reasons, is also far from being constant. But the other gases are apparently present in the percentage given wherever in the whole troposphere a sample of atmospheric air may be collected. (Statements to the contrary in the older literature,

by Wigand, Tetens and E. Erdmann and H. Lange, were based on very few inaccurate experiments and can be regarded as disproved; it is most unfortunate that they should still be quoted.*) This equal distribution is perfectly understandable as an effect of the frequent stirring of the troposphere by winds; but if it be true that in the stratosphere no mixing beyond the slow one due to diffusion takes place, we should expect to find there a partial separation of the gases according to their different densities. A careful chemical analysis of air samples taken at various heights in the stratosphere is, therefore, a means of testing the question of the stillness of the stratosphere air.

As to the chemical analysis of air, we may confine ourselves to the determination of a few representative constituents. By far the easiest measurement is that of oxygen, and this gas has, therefore, been chosen by most laboratories; its absorption can be effected by phosphorus, heated copper or pyrogallie acid, or it may be removed by catalytic combustion with hydrogen. Its density, however, is only slightly greater than that of air (see Table 2) and for this reason it is not nearly the best for the present purpose; but the determination of the heavier argon is not so

* See, for example, NATURE, 137, 459 (1936).

simple, and that of the minute traces of the very heavy gases, krypton and xenon, quite impossible in small air samples. As a specimen of a gas lighter than air, helium is the most suitable, since the lightest known gas, hydrogen, is not present

TABLE 2.
DENSITIES OF THE ATMOSPHERIC GASES.

	Formula	Molecular weight (O = 16.000)	Density (Air = 1.000)
Helium	He	4.002	0.1381
Neon	Ne	20.183	0.6963
Nitrogen	N ₂	28.016	0.9670
Oxygen	O ₂	32.000	1.1053
Argon	A	39.944	1.377
Carbon dioxide	CO ₂	44.00	1.529
Ozone	O ₃	48.000	1.624
Krypton	Kr	83.7	2.868
Xenon	X	131.3	4.525

in any measurable quantity; for the determination of helium we have developed a micro-method which enabled us to measure quantities of a few millionths of a cubic centimetre with an accuracy of 1 per cent.

(To be continued.)

Obituary Notices

Dr. R. J. Tillyard, F.R.S.

THE death of Dr. R. J. Tillyard took place in Australia on January 13, as the result of a motor-car accident on the road between Canberra and Sydney. Since Tillyard was one of the best known entomologists of the present day, his decease will come as a shock to his colleagues in many parts of the world.

Born on January 31, 1881, Robin John Tillyard was the son of J. J. Tillyard, of Norwich. His education was at Dover College and Queens' College, Cambridge, where he gained a mathematical scholarship. He became senior optime in 1903 and graduated M.A. in 1907. Ill-health, especially rheumatism, led him to seek a livelihood abroad, and he went to Australia in 1904 as mathematics master at Sidney Grammar School. In 1909 he married Miss Patricia Craske, a daughter of Mr. W. R. Craske, J.P., of Borstal, Rochester.

On gaining a Government studentship at the University of Sydney, Tillyard relinquished the career of schoolmaster and in 1915 became Macleay fellow of the Linnean Society of New South Wales, an office which he held until 1920. A short period before the Great War he became involved in a railway accident which incapacitated him for a long time and permanently altered his bodily figure. During these years he had a young family to provide for

on slender means. At this juncture, he owed much to his wife's skill and devotion in managing all family affairs over a difficult period. In spite of being still an invalid, he took a B.Sc. research degree at the University of Sydney and, some years later, became a D.Sc. In 1920 he was appointed chief of the Department of Biology at the Cawthron Institute, Nelson, New Zealand. Tillyard remained at Nelson until 1928, when he became Chief Commonwealth Entomologist for Australia—a new and highly paid post with more exacting duties. He held this post for six years but, owing to health reasons, he had to retire, the Federal Government granting him a proportional pension.

Tillyard's early researches were concerned with dragonflies and, beginning from about 1905, he published a long series of papers on these insects, mostly in the *Proceedings of the Linnean Society of New South Wales*. His most important original study in this field is his paper "On the Rectal Breathing Apparatus of Anisopterid Larvæ" which was published by the Linnean Society of London (1916). It is a work of outstanding merit and secured for him the Crisp Medal and Award of that Society. About 1915 he became interested in the wonderful Neuroptera of Australia, publishing many papers on these insects. His work on the Chrysopidæ showed with remarkable clarity how the intricate venation