of those plants which were able to fix it, at the same time showing that leguminous plants grown in sterilised soil were no more able to fix nitrogen than were other plants similarly grown. It was left to later workers, however, to supply the clue which led to the discovery that soil bacteria play an important part in the fixation of atmospheric nitrogen. Boussingault opposed the view of Liebig that plants obtained their nitrogen as well as their carbon dioxide directly from the air. With reference to the vexed problem of the nitrogen content of manures, he wrote:

"Si M. Liebig a raison, nous somme, nous autres cultivateurs, de bien gros maladroits: nous nous donnons beaucoup de peine pour conduire, pendant l'hiver, nos fumiers sur nos terres, nos attelages nous coutent cher: si le matière minérale des engrais est seul utile, brulons nos fumiers et, pour le transport, une brouette fera l'affaire".

As time went on, Boussingault expanded his researches to embrace the whole range of agriculture and kindred sciences. His work on the nitrogen metabolism of plants led directly to the protein metabolism of the animals which fed on the crops on one hand and to the carbohydrate metabolism of plants on the other. Much of his later published work deals with the problems of plant and animal physiology in the more restricted sense.

In 1839, Boussingault left Lyons and was appointed to the chair of agricultural and analytical chemistry in Paris, where he remained for many years. He was elected to the Paris Academy of Sciences in the same year. The Council of the Royal Society awarded him the Copley Medal in 1878. For a short term, he represented the Bas-Rhin in the National Assembly, but change of Government led to his being defeated after some three years.

Most of Boussingault's life was devoted to his studies on agricultural chemistry, and he published his collected papers under the title of "Agronomie, chemie agricole et physiologie". Unfortunately, the experiments on the farm at Bechelbronn were discontinued after some years, and although Boussingault lived until 1887, he had long before been compelled to conclude his original field experiments. The lead given by Boussingault was, however, followed by Ludwig, by Lawes and by many other workers, and some nine years after Boussingault had laid out his original experimental plots, Lawes at Rothamsted began the experiments which have become classical in agricultural research.

Boussingault—the father of modern agricultural chemistry—must be judged not only by the immense volume of work which he himself carried out, but also by the amazing effect his application of exact measurement and experimentation to agriculture has had on that science.

Interpretation of Animal Behaviour

NO topic of biological discussion is better able to revive old controversies and established cleavages in opinion than the methodology of animal psychology. It owes this propensity to the fact that the comparative study of behaviour is not, and never has been, integrated into a single consistent science. The subject is so wide, its interests so many and varied, that not only may its methods range from those of physiology to those of systematic 'nature study', but also, as was shown in the discussion on the "Interpretation of Animal Behaviour" which took place in Sections D (Zoology) and J (Psychology) at the recent Aberdeen meeting of the British Association, many of its disciples may prove to be both lacking in knowledge of the interests, and of necessity opposed to the outlook, of investigators engaged in trying to advance the same branch of knowledge along paths different from their own. If it did nothing else, the Aberdeen discussion at least clearly defined for animal psychology the opposition between the vitalistic, teleological and subjective points of view on one hand, and the objective and mechanistic on the other.

The primary objection raised against the mechanistic interpretation of behaviour was that animals are not concatenations of mechanical systems in action, and that accordingly their behaviour can neither be adequately explained in mechanical terms, nor satisfactorily investigated by causal-analytical methods alone (to use the term employed by Dr. E. S. Russell in his presidential address to Section D (Zoology)[1]). In defence of this view, Dr. Bierens de Haan affirmed that an essential characteristic of the behaviour of living things which distinguishes it from that of non-living systems is organised purposiveness or directiveness. Prof. William McDougall penetrated further into teleology, insisting that it is not enough to accept purpose as a general principle; it is essential, he considers, that it be recognised that all animal activity is 'goal-seeking', for in the appreciation of this fact lies true understanding.

Those opposed to mechanism were, however, not content to argue against the causal-analytical investigation of animal behaviour on account of a teleological distinction alone. They also suggested, as Dr. E. S. Russell implied[2], that in any event mechanistic analysis must be fundamentally unsound if modern physics has had to abandon determinism, and as a further argument in support of this view, Dr. Bierens de Haan protested that the mechanistic analysis of a form of activity gives only a number of parts—for example, reflexes—which in themselves provide no understanding of the behaviour, since the bond linking them in the intact animal is missing. This criticism of scientific method and interpretation, with which Dr. Russell is in sympathy, plainly owes its inspiration to the philosophies of emergent evolution and holism.

Not unexpectedly, these views found little favour with those who advocated the mechanistic approach. An appearance of purpose and adaptation, Dr. S. Zuckerman pointed out, is not a characteristic of the activity of living things only. It is manifested equally well in the inorganic world, the scientific exploration of which is nevertheless conducted without the help of teleological speculation. Moreover, as the same speaker remarked, it is misleading to argue, on the basis of some of the uncertainties of atomic physics and on the strength of the opinions of popular expositors of physical science, that mechanistic determinism is dead. In support of this opinion, we may recall a sentence from a recent leading article in NATURE[3]: "Newtonian mechanics, so far from being in ruins, is more firmly established than ever as the form taken in ordinary circumstances by the mechanics of relativity".

The argument that the parts produced by causal-analytical study are an inadequate interpretation of behaviour—in other words, the argument that the whole is greater than the sum of its parts—was countered, and in what is the obvious way from a scientific point of view, by refuting it as a criticism based both upon a primary misinterpretation of scientific method, and upon a misunderstanding of the province of science. A serious attack was also made on Prof. McDougall's teleological doctrines. Quite apart from other considerations, Dr. Knight pointed out that 'goal-seeking' is as much a characteristic of the behaviour of the roots of a plant as it is of the behaviour of animals.

It is difficult to define precisely what those opposed to the usual experimental methods in the study of behaviour offered in their stead. It was suggested that the principle of organisation and the concept of the functional whole should form guiding lines to investigations of animal behaviour. Exactly how this would alter present methods of investigation was not revealed, for it is plain, as the mechanists argued, that the concept of organisation is an implicit premise in any form of behaviour which an experimentalist sets out to investigate. The most definite suggestion made by the vitalists for the improvement of present experimental methods in comparative psychology was simply a plea to amplify descriptions of animal behaviour with terms derived from introspective human psychology. This proposal was immediately decried by the mechanists, as being a reactionary step which would bring animal psychology back again to its discredited anecdotal phase.

In attempting to judge of the merits of the opposed points of view expressed in Aberdeen, it is well to remember that animal psychology as an experimental laboratory science is a very recent innovation. It is barely forty years since the subject was born out of a mist of anecdote and anthropomorphic description. It was then that Lloyd Morgan made the statement—now revered as 'the canon of Morgan'—that "in no case may we interpret an action as the outcome of the exercise of a higher psychical faculty, if it can be interpreted as the outcome of one which stands lower in the psychological scale". As a guide to scientific progress, the dictum seems rather inadequate to-day; yet this canon is the only check to the limits which subjective interpretations of animal behaviour may reach, and like all pieces of similar advice, there are no possible limits to the varying complexions it may present to different individuals. Abstract theorising, without fixed standards, brought introspective psychology nowhere as a science. Only by the adoption and application of statistical methods to such of its subject data as were capable of precise definition, has it been in any way prevented from foundering in a torrent of conflicting waves of opinion. *Per se* and in isolation, an interpretation in subjective terms of an act of another organism is not material for scientific treatment; and even less scientific is preoccupation with teleology.

It may well be, as Dr. Bierens de Haan declared, that a purely objective attitude in the study of animal behaviour provides an unsympathetic account of the ways of animals. Be this as it may, one can be certain that its promoters intended the Aberdeen discussion as a statement of how animal behaviour is to be scientifically interpreted, and in the circumstances one cannot doubt that objective analysis alone will provide us with an acceptably expressed and integrated body of knowledge. That, after all, is the business of animal psychology as a science, regardless of the unfounded claims of extreme behaviourists, and in spite of the preoccupation of another school with teleology and other purely philosophical issues.

If the achievement of an exact and organised science of animal behaviour proves slow, let us remember Freud's admonition[4]: ". . . it looks as though people did not expect from psychology progress in knowledge, but some other kind of satisfaction; every unsolved problem, every acknowledged uncertainty, is turned into a ground of complaint against it". Such an opinion from one whose chief activities have been concerned with the subjective world reflects poorly on those who condemn an objective approach to psychology because the fruits it has yielded are as yet neither rich enough nor abundant enough for their taste.

[1] "The Advancement of Science, 1934". British Association.
[2] *ibid.*
[3] NATURE, **134**, 340, Sept. 8, 1934.
[4] "New Introductory Lecture on Psycho-Analysis".

Obituary

Prof. Karl von Linde

PROF. KARL VON LINDE, who died on November 16 at the age of ninety-two years, was for more than half a century prominent in the refrigeration industry. He was born on June 11, 1842, in Berndorf, and studied at the Erdgenoss Polytechnic, Zurich, where Zeuner taught the theory of machines. In 1868, at twenty-six years of age, Linde became extraordinary professor of mechanical science at the Munich technical college which had just been founded. In 1870 he produced his main paper on "The Extraction of Heat at Low Temperatures through Mechanical Means", in which he proved that none of the refrigerating machines hitherto built had given more than one-fifth of the theoretical capacity. In 1874 he introduced the ammonia refrigerating machine, the first patents on the ammonia compression machine having been taken out by him in 1870. Linde's machine, besides being thermodynamically efficient, was characterised by the excellence of its mechanical design.

In 1891, the Linde British Refrigeration Co. supplied meat freezing plants to New Zealand and Australia, thus participating in laying the foundation of what is now a huge frozen meat industry.

In Germany Linde's patents were exploited by the Lindes Eismaschinen AG. founded at Wiesbaden in 1879. In 1891 he retired from the chairmanship of the company in order to resume his work at the Technical High School, Munich.

Another notable invention of Linde was his air liquefying and oxygen producing apparatus. The apparatus is described in British Specification No. 12528 of 1895, and it comprises an air compressor communicating with a reversed flow heat interchanger having two tubes of different diameters and about 300 ft. long; one tube is inserted in the other so as to leave an annular space and both are coiled helically, the coils being insulated by raw sheep's wool.

The compressed gas, after expansion at the regulating valve, flows back in the annular space to the compressor, whilst after operating for some time a portion is liquefied. In the same patent, Linde described his apparatus for obtaining oxygen from liquid air by fractional evaporation. The products were substantially pure oxygen and nitrogen mixed with a rather large quantity of oxygen. The purer the oxygen the less was the yield. In a subsequent improvement Linde treated the liquid air in a rectifying column and completed the process of separating the oxygen and nitrogen by a fractional evaporation.

After devising the method for the production of liquid air, Linde found an application for the liquid rich in oxygen obtained by the partial evaporation of liquefied air. He showed that when mixed with wood charcoal or other combustible material a powerful explosive was obtained.

Linde's interest in low temperature technology continued throughout his life, and at the age of eighty-three he applied refrigeration to the problem of separating from coke oven gas the constituents hydrogen, methane, carbon monoxide and nitrogen.

Linde was ennobled for his services to science.

E. G.

Mrs. H. S. Williamson

WE regret to record the death on December 4 of Mrs. H. S. Williamson. She was born in 1884, educated at the Royal Holloway College and published her early papers in her maiden name of Chambers from 1908 onwards. She held posts at the Universities of Sheffield and Belfast, and at the Royal Holloway College. In November 1914, she married Ernest Lee, whose work on leaf-fall indicated his great promise; he was killed in action in 1915. In the autumn of that year, she trained for bacteriological work and replaced in the Seamen's Hospital at Greenwich an official proceeding on active service.

In 1920, while employed at the Imperial College of Science and Technology, she married Mr. J. W. Williamson, secretary to the British Scientific Instrument Research Association. In 1926 she accepted the post of research assistant to the professor of botany at Birkbeck College, and was joint author of a series of papers on the fungi.

Mrs. Williamson possessed an unusually fine technique, was a careful and critical observer and, as many can testify, an excellent friend and colleague.

H. C. I. G.-V.

WE regret to announce the following deaths:

Mr. J. A. Brodie, formerly city engineer of Liverpool, president of the Institution of Civil Engineers in 1921, a pioneer in modern methods of road construction, on November 16, aged seventy-six years.

Prof. S. H. Gaiger, professor of veterinary pathology in the University of Liverpool since 1926, and president of the Royal College of Veterinary Surgeons, on December 14, aged fifty years.

Prof. S. P. Mulliken, professor of organic chemistry in the Massachusetts Institute of Technology, on October 24, aged sixty-nine years.