most thoroughly studied in real animals) is a specialized attribute of animals with highly developed brains, and that the elaborate form of behaviour in sub-mammals known generally as 'instinctive' is a combination of reflexive patterns which have not been subordinated to the learned modes typical of mammals and particularly of primates.

Another model has been built to show how the characters of the innate releaser mechanism can be achieved in a single mechanism, and how this form of behaviour may vary with activity and be particularly vulnerable to changes in the internal environments such as 'starvation' or 'satiety'.

Of greater relevance to the study of human mentality is the imitation of the process of learning by association or conditioned reflex formation. Analysis of this process as it actually occurs in animals suggested that, in the simplest case, it could be considered as involving a chain of seven distinct operations, known respectively as: (1) differentiation of specific stimuli; (2) extension of neutral stimuli; (3) mixing of (1) and (2); (4) summation of degrees of coincidence achieved in (3); (5) activation of storage system when degree of coincidence in (4) has exceeded chance expectation; (6) storage of the information that the coincidence has exceeded chance expectation; (7) combination of the stored information with a fresh neutral stimulus to provide a novel mode of responding to the previously neutral, now 'conditioned', stimulus.

These operations can be embodied in a working model, and such a model can be seen to 'learn' in the sense that it can discriminate between random events and those which are significantly related, and can then respond to a part of the significant association as if the whole were present. An important inference is that learning in this sense and pattern recognition are essentially the same process. A pattern may be defined as a class of relations between events which is likely to operate a learning mechanism.

The actual models (known as *Machina docilis*) of learning display several peculiarities which at first seemed to be faults but may be instructive. When set up to demonstrate a defensive rather than an appetitive conditioned reflex, it was found that the 'learned' pattern was often self-maintaining; it was not easily extinguished by lack of reinforcement. Reconsideration of animal behaviour and of human neuroses suggests that this may indeed be a property of complex behaviour based on the avoidance of pain, and that the intractability of obsessional and compulsive neuroses may be due to their liability to

self-reinforcement. Again, when a neutral stimulus is given to the model in a carefully timed rhythm, the system can be induced to respond as if it had 'invented' a specific stimulus which it had never, in fact, experienced. This rudiment of originality also seemed tiresome at first; but bizarre illusions and fantasies can, in fact, be induced in some human subjects by rhythmic stimuli and it is possible that, as in the model, this effect may be due to the direct activation of a storage circuit by the cumulative action of the imposed rhythm.

The fundamental notion underlying this description of associative thinking is that mentality is based on a statistical or probabilistic analysis of experience rather than a logical or deterministic one. In fact, mentality could be defined as the rate of change of behaviour induced by statistically significant associations. This notion is not so far removed as it may seem from the real problem of brain and its function; a capacity to learn is the diagnostic character of brain, and the hypothesis that a learning brain is perpetually scanning the world of experience for statistically significant information suggests a fresh experimental approach to the problem of how animals learn. In fact, reconsideration of the protocols of conditioned reflex experiments designed to induce 'experimental neuroses' has disclosed a previously unsuspected pattern in those stimulus arrangements which were found to disturb the animals. It looks very much as though an animal—human or otherwise—in a learning situation is acting as if it were a statistical computer set to accept, as significant, odds greater than 1,000 to 1 against chance association. If the basis of learning is the computation of contingency, then most animals are considerably more sceptical than professional statisticians, who generally consider odds of 100 to 1 against chance as indicating significance.

Experiments suggested by these analogues of reflexive and associative behaviour are now in progress. Naturally, the hypotheses will be found inadequate; but there is no reason why other models should not be designed to match observation still more closely. There is even a possibility that, in the more distant future, devices that began as instructive toys may develop into powerful tools. We are already entering a phase of our culture when our arithmetic, algebra and even our material production are being delegated to mechanical extensions of our five wits. Eventually, the mental functions of conjecture and imagination may also be shared with the successors of these humble mechanical 'protozoa'.

OBITUARIES

Prof. H. F. Baker, F.R.S.

HENRY FREDERICK BAKER, who was Lowndean professor of astronomy and geometry at Cambridge from 1914 until 1936, died on March 17. His name is chiefly remembered as the founder of a vigorous and distinctive school of geometry, but his influence on the mathematical life of Britain was wider than this.

Baker was born in 1866 and was educated at the Perse School and at St. John's College, Cambridge. His progress as a student was impeccable—joint Senior Wrangler in 1887, first division of the first class in the Mathematical Tripos of 1888, and Smith's

Prizeman in 1889, in which year he was elected to a fellowship at St. John's which he held until his death nearly sixty-seven years later. So at the age of twenty-three he embarked on the career of a Cambridge don which he was to follow throughout his life. He did not travel widely; but he had contacts with mathematicians in all parts of the globe, and a visit to Göttingen to study under Felix Klein had a decisive influence on his development as a mathematician. He thus began his work in Cambridge while Cayley, Stokes and Adams were still the dominant influences in Cambridge mathematics. Cayley, who shared with Klein the role of chief formative influence in Baker's mathematics, did not

die until 1894. It was very appropriate that, when a lectureship was founded in memory of Cayley, Baker was appointed the first holder, in 1903.

Baker quickly threw himself into the work of a college don, and was soon carrying a load of teaching which would make the modern don shudder. He had to teach all the subjects required for the Mathematical Tripos; but in his formal lectures he specialized in the theory of functions and geometry. His principal interest at this time was the theory of algebraic functions, and in spite of his heavy teaching duties he managed to get through a prodigious amount of reading. His first book, "Abel's Theorem and the Allied Theory" (1897), is a monumental work, and his second book, "Multiply Periodic Functions" (1907), is a thorough study of the theory associated with theta functions of two variables. But his papers cover a much wider range—the theory of functions, continuous groups, multiple integrals, projective and algebraic geometry. While a good deal of his original work of this period has been superseded by modern developments, much of permanent value remains, and I recall the pleasure which it gave Baker, only a couple of years ago, to supply reprints of a paper fifty years old which a leading group of American mathematicians was anxious to obtain.

In 1913, Sir Robert Ball, the Lowndean professor who had followed Adams, died, and early in 1914 Baker was elected his successor. The six previous holders of the chair had all been astronomers, and the University statutes of the period did not explicitly allow the Lowndean professor to specialize either in astronomy or in geometry; so Baker, with a characteristic devotion to duty, immediately offered a course on periodic orbits, not in place of, but in addition to, the lectures on the theory of functions which he had been scheduled to give before his election. He kept up his lectures on dynamical astronomy for many years, and a number of distinguished astronomers have spoken of these lectures in the highest terms. But from 1914 onwards he concentrated more and more on geometry, and for some years before he retired his lectures and writings were all on geometry. During his long retirement he continued to work on geometry, and in 1943 he published "An Introduction to Plane Geometry", followed in 1946 by a Cambridge Mathematical Tract, "A locus with 25920 linear self-transformations"; and only two months before his death he completed, in spite of failing eyesight, a commentary on some of his earlier books.

After the First World War, Baker set about building up a school of geometry, and succeeded so well that the 'Baker school' still has its distinctive character. At first the emphasis was primarily on projective geometry, along the lines of von Standt and Reye. To this period we owe the first four volumes of his "Principles of Geometry", which became the bible of his followers. This work reaches its climax in the fourth volume, which deals with the numerous special configurations and loci in four dimensions and their relations with classical configurations such as the double-six in three dimensions, with infectious enthusiasm and many characteristic touches. Later, he lectured more on the birational theory of surfaces, as developed by the Italian geometers, and out of these lectures grew the fifth and sixth volumes of his "Principles". His interest in Italian geometry, however, began much earlier, arising naturally from his work on algebraic functions, and in 1912 he made it the subject of his presidential address to the

London Mathematical Society, perhaps the most influential single article he ever wrote. But what remains most vividly in the minds of all his pupils is the burning enthusiasm he brought to all his teaching, and the enthusiasm he kindled in his audiences. No one ever attended his lectures on geometry without gaining something which remained with him throughout his life. W. V. D. HODGE

Prof. Léon Bertin

ON February 4, in his sixtieth year, Prof. Léon Bertin was killed in a motor-car accident on the frozen roads outside Paris. He had held the chair of herpetology and ichthyology at the Muséum National d'Histoire Naturelle since the death of Pellegrin in 1944.

Bertin graduated at the *École Normale Supérieure* of Paris in 1920 and was awarded a bursary to study for a doctorate. Under Prof. Bouvier he had been initiated, as he said, "au dur métier de la systématique" in the field of entomology, and he now took up the study of sticklebacks in a way that would have astonished Mr. Pickwick. Johannes Schmidt had just demonstrated the value of biometry in analysing the races of *Zoarces* and contrasting their diversity with the homogeneity of the populations of the European eel. Bertin applied like methods to sticklebacks and published on them a series of papers culminating in the classical "Recherches bionomiques, biométriques et systématiques sur les *Épinoches* (*Gasterostéidés*)" (1925), which won him his doctorate. The three-spined stickleback shows, in the amount of dermal ossification, a diversity which, expressed in the number of lateral shields, lends itself to numerical analysis. By examining ten thousand specimens from forty-five localities in France and North Africa, Bertin was able to correlate the degree of armature with age, salinity and latitude. Although later work by Heuts has shown that his conclusions were over-simplified, Bertin produced order from chaos and laid a firm foundation on which others have built. The French sticklebacks proved to have a life-span of fourteen to eighteen months. Later, Bertin studied large samples from Iceland and Greenland and demonstrated that these do not become sexually mature until their third or fourth summer, and that they thus conform to the rule of longer life-span in higher latitudes.

This work was followed by studies on bathypelagic eels and then on those enigmatic eel-like fishes, the *Lymeri*. Bertin was entrusted with rare and precious material of these groups collected during the cruises of the *Dana*. As well as a number of smaller papers, he published three *Dana* Reports on them (the first in collaboration with Roule), and he had work on them in hand at the time of his death.

Throughout his career Bertin was associated with the University of Paris and the Museum. His courses at the University were much appreciated, and that on the eels was published in book form in 1942.

While still 'Sous-Directeur' at the Museum, Bertin organized and directed the indexing of the rich but neglected departmental library of offprints and journals. He appreciated the effect of environment on his staff no less than on the sticklebacks, and visitors to his laboratory in the *Jardin des Plantes* after the War were impressed by its pleasing decoration and efficient organization as well as by the ready assistance they received. No longer do we read in