Man was almost certainly associated with them, but nothing is known to distinguish this race from modern South American Indians. The supposed ancestors of the human family reported by Florentino Ameghino from the Tertiary rocks of Argentina are due to erroneous interpretation of the fossils, as already pointed out by Hrdlička and others.

The first fossilised remains of man in the South American continent were discovered exactly a hundred years ago in the caves of Minas Geraes, Brazil, by the Danish naturalist, Dr. Peter Wilhelm Lund, whose centenary has just been celebrated by the scientific men of Brazil in Lagoa Santa and Bello Horizonte. Under the direction of Prof. Anibal Mattos, three volumes have been published in Bello Horizonte, giving an account of Lund's researches, with a Portuguese translation of his scientific papers.

Some years ago the late Dr. Francisco P. Moreno, Dr. Rudolf Hauthal and I, described the discovery of the dried skin and other remains of an extinct ground sloth (*Neomylodon* or *Grypotherium*), with fragments of other extinct mammals, in a cave in Last Hope Inlet, Patagonia. Here again, the presence of fires, cut and worked bone, and masses of hay cut for food for the ground sloth, led us to infer that man lived in Patagonia with the various Pleistocene mammals which are now extinct.

The races of men who eventually reached New Zealand and other remote islands were so far advanced in civilised life that they scarcely concern a palæontologist. They only interest him on account of the disturbance of the existing wild life and the extinctions which they have caused. The ethnologist now joins the human anatomist in attempting to explain the distribution of these people and to discover their relationships. They occupy a lowly sphere in the *modern* world.

The Meaning of Probability

By Dr. Herbert Dingle

THE subject of probability originated in the consideration of actual but trivial problems. Its obvious attractions as a field for the exercise of mathematical ingenuity soon gave it a predominantly mathematical aspect, and in spite of its application to certain practical activities such as those of insurance companies, and its significance for statistical mechanics, it has until recently been treated as a branch of pure mathematics. Nevertheless, the word has a meaning in ordinary life among those who never concern themselves with mathematics. Such people have often to act without sufficient knowledge to predict with certainty the effect of their actions, and they do so in accordance with the 'probabilities' of the case. They do not calculate a numerical magnitude; they simply act in the way which they feel to be 'most likely' to produce the result they desire. Obviously, it is desirable that the precise scientific definition of probability should approximate as closely as possible to the pre-existing, indefinite conception which directs the majority of our actions. If it does not do so, it is not necessarily illegitimate mathematically or even physically, but it would then be better represented by another word.

Now in recent years probability has entered physics in a much more vital way than previously. This introduces another complication. In order to obtain physical credentials, concepts have now to satisfy certain conditions which mathematics does not impose, and, as we shall see, probability in its customary mathematical sense does not necessarily satisfy those conditions. We have therefore a threefold aspect of probability—an ordinary, everyday aspect, a mathematical aspect and a physical aspect; and unless hopeless confusion is to result, we must either use the word only to represent a conception which is satisfactory from all three aspects, or, alternatively, restrict our application of any narrower conception we may employ to those fields to which it legitimately belongs.

We must notice, however, that even when we have done our best to be precise, the question necessarily retains some vagueness—for two reasons. In the first place, when one wishes to convert an indefinite into a precise conception, one has obviously a certain latitude of choice, just as there was a certain latitude of choice in selecting a particular 'unknown soldier' to represent the general war hero. This affects our attempt to frame a mathematical or physical definition agreeing with our everyday use of the word. In the second place, the very idea of probability, however precise it is made, has an intrinsic vagueness, since, unless it has the value 1 or 0 (speaking in terms of the ordinary mathematical definition), it cannot be inconsistent with any single experiment made to test it. This affects our attempt to make the physical equivalent to the mathematical definition.

Both these difficulties are well illustrated by the problem which is the subject of discussion between Dr. T. E. Sterne and myself[1]. That problem is as follows: "If A and D each speaks the truth once in three times independently, and A says that D lies, what is the probability that D speaks the truth?" Let us consider first the relation of the mathematical to the everyday treatment of this problem; we will consider its relation to the physical treatment later.

We have here an event (D's remark) to which we want to assign the probability that it has a certain characteristic (truth). We have two independent pieces of information bearing on it: (1) statistics concerning D's statements; (2) a comment by A, whose character is known. The difference between Dr. Sterne and myself is that I regard these pieces of information as completely independent, so that any combination of them is purely artificial, whereas he puts them in the same class, obtains a probability by combining them, and claims that it is significant because it is unambiguous.

Now, as we have seen, there is no final proof one way or the other. I would say that a probability derived from either (1) or (2) by itself would be within the limits of ordinary conceptions —like taking two different victims of the Battle of the Marne for the unknown soldier—but that a probability derived from a combination of (1) and (2) would go outside those limits; it would correspond to the choice of, say, a Crimean warrior. The essential vagueness of the first kind prevents a rigid proof of this, but I can give examples to show where, as it seems to me, Dr. Sterne has been misled.

In combining (1) and (2), Dr. Sterne is combining data which have an obvious but inessential resemblance: they are both concerned with people's statements. But those statements are used in different ways. D's character gives us a statistical probability, but A's character, *in reference to the statement of D in question*, has no statistical aspect; the datum would be unaltered if D had never before spoken. In my review of Sir Arthur Eddington's book, "New Pathways in Science", which originated this discussion[2], I tried to make the two sources of data as distinct as possible by citing an analogous problem involving the 'statistical' and the 'cause-and-effect' probabilities of a horse's success in a race. Here the essence of the problem is the same—we have still two independent sets of data bearing on a particular event—but, the irrelevant superficial resemblance having been removed, it is clear that a combination of those data is quite artificial.

What one does in such problems is, it seems to me, to choose first which kind of data to trust, and ignore the other. A gambler, I imagine (I confess to inexperience in these matters), usually decides in favour of the horse that seems most likely to win, and ignores statistics of what has happened to such horses in the past. Another example may make the point even clearer. If Ohm's law has been experimentally verified 9,999 times out of 10,000, and P, who speaks the truth once in 10,000 times, says that it is true, what is the probability that it is false? My own opinion is that no one would pay any heed to the unspeakable P, but Dr. Sterne's method would give a probability $\frac{1}{2}$—that is, the law would be as likely to be false as true. In the problem of D's statement, I am convinced that if there were any hesitation in one's mind, it would be whether to put trust in A or D: it would have nothing to do with any combination of their testimony.

Let us, however, turn to the physical question, which is by far the more important. One of the chief features of modern physics is the conscious realisation and practice of the principle that no statement shall be accorded physical meaning unless it can be tested by physical experiment. It was on this ground that Einstein rejected the notion of absolute simultaneity of spatially separated events: since there is no physical means of determining absolutely if two such events are simultaneous, there is no meaning in calling them so. It was on the same ground that Heisenberg rejected the simultaneous evaluation of certain conjugate characteristics of a mechanical system: since there is no means of determining, for example, the precise momentum of the system at a definite position in space, there is no meaning in saying that the system has simultaneous position and momentum.

The essential vagueness of the second kind mentioned above therefore seems to rule out probability as a physical conception. If we state that the probability that a certain event will occur is $\frac{1}{3}$, then our statement cannot be checked by seeing if it does occur: whether it occurs or not, the statement may still be either true or false. Yet, in spite of this obvious disqualification, probability has stepped into the place vacated by conceptions which the principle in question has expelled. What is the explanation?

It is simply that probability in physics is purely symbolical: it is a metaphor expressing certain experimental results. For example, we find by experiment that in certain definite circumstances a screen is twice as brightly illuminated at one place, A, as at another, B. Now begins the metaphor. We imagine the light to consist of groups of 'photons', to which we assign the property of illuminating the screen in proportion to their number; hence we must imagine that twice as many photons fall on A as on B. To enlarge our conception we ask why this is so, but we can get no answer. We must therefore rest content with saying that the 'probability' that a particular photon will go to A is twice as great as the probability that it will go to B. We cannot justify this physically if it is taken in any literal sense because, as we have seen, it cannot be tested. It has physical meaning only if we take it as a metaphorical expression of what we observe. We express the *observed behaviour of many* (arbitrarily imagined) photons by attaching a *hypothetical property to each* of them.

Let us now test the physical reality of the probabilities involved in our problem. The records of D's statements alone give a result (let us call it the 'probability'), $\frac{1}{3}$. A's comment alone gives a result (the 'likelihood'), $\frac{2}{3}$. Dr. Sterne's "association table" gives a result (the 'chance'), $\frac{1}{2}$. The probability and the likelihood are obviously real, for they symbolise the results of experiments which have been made. The chance, however, is in different case. It purports to mean, as Dr. Sterne himself says, that if A says many times that D lies, half of his comments will be true. But there is no experimental evidence for this, for the data do not tell us that A has made more than one such comment. We cannot, furthermore, make an experiment to test it (strictly speaking, a superfluous consideration, for 'chance' is intended to represent not prediction but existing fact), for even if we could bring A and D together, make D speak many times, and induce A to comment on each of his remarks, we could have no guarantee that the conditions would not violate the postulate—that, in fact, A and D would continue to speak truth or lie 'independently'. Hence 'chance' can have no physical significance, for it symbolises, not experimental results but a mathematical process.

The questions involved in this discussion are far more important than may appear on the surface. If the chapter on probability in Sir Arthur Eddington's book had been merely an account of a mathematical theory, it would, in spite of its interest and value, scarcely have called for lengthy controversy in a general scientific journal. It was included, however, because of the importance of probability in modern physical theory, and the reader would naturally suppose that what he was reading about had a physical application. This is a relatively harmless example of one of the most regrettable characteristics of our time. Probability, which enters physics as a symbol for expressing actual observations, emerges in scientific romances, amid the blare of trumpets, dressed as a general custodian of any sort of knowledge or rumour that may drift along, and purely objective systems are spoken of as 'waves of knowledge' or 'waves of probability', as though inorganic Nature is altered when someone speaks about it. The consequence is that the general public is led to believe that Nature is dissolved into pure subjectivity.

It is all the result of allowing mathematics, which is a good servant, to become a bad master. Instead of observation, the true test of physical reality, we are offered mathematical uniqueness. So insidious is this evil that Dr. Sterne appears to find it incredible that I describe as a "meaningless mathematical function" an expression which is immediately seen to be so by the foremost criterion of the physics in which he himself has done such brilliant work. It has even been suggested that mathematics is divine, when it is not even physical. It is much to be hoped that the true relations between mathematics and physics will be clarified, for the sake of both physical progress and general understanding of recent advances of thought.

D's statement	C's statement	B's statement	A's statement
T 27	$D + T$ 9	$C \rightarrow D + T$ 3	$B \rightarrow C \rightarrow D + T$ 1
			$B \leftarrow C \rightarrow D + L$ 2
		$C \leftarrow D + L$ 6	$B \rightarrow C \leftarrow D + T$ 2
			$B \leftarrow C \leftarrow D + L$ 4
	$D - L$ 18	$C \rightarrow D - T$ 6	$B \rightarrow C \rightarrow D - T$ 2
			$B \leftarrow C \rightarrow D - L$ 4
		$C \leftarrow D - L$ 12	$B \rightarrow C \leftarrow D - T$ 4
			$B \leftarrow C \leftarrow D - L$ 8
L 54	$D - T$ 18	$C \rightarrow D - T$ 6	$B \rightarrow C \rightarrow D - T$ 2
			$B \leftarrow C \rightarrow D - L$ 4
		$C \leftarrow D - L$ 12	$B \rightarrow C \leftarrow D - T$ 4
			$B \leftarrow C \leftarrow D - L$ 8
	$D + L$ 36	$C \rightarrow D + T$ 12	$B \rightarrow C \rightarrow D + T$ 4
			$B \leftarrow C \rightarrow D + L$ 8
		$C \leftarrow D + L$ 24	$B \rightarrow C \leftarrow D + T$ 8
			$B \leftarrow C \leftarrow D + L$ 16

If, after this, I may be allowed a word on the purely mathematical question, I would say that, if I have understood Dr. Sterne's contingency table aright, I do not agree with him that it cannot be constructed for Sir Arthur Eddington's original problem. If that were so, it would of course indicate a defect of his method of treatment, because the problem (if we allow the assumption, which must be made in the simplified problem as well as in this, that if D does not lie he necessarily speaks the truth) is unambiguous. I had, however, constructed what I believe to be such a table before his first letter appeared. It is given above.

81 statements by D are considered, and each remark in the table is followed by "T" or "L", representing "truth" or "lie", and by the number of such remarks in the 81 cases. For brevity, the following symbols have been adopted :

$\rightarrow$ means "asserts that" ; $+$ means "tells the truth";
$\leftarrow$ .. "denies that" ; $-$,, "lies".

It will be seen that only lines 6 and 10 of A's statements satisfy the conditions of the problem, giving 4 cases in which D lies to 4 in which he speaks the truth, so that the 'chance' that D speaks the truth is $\frac{1}{2}$, as in the simplified problem. (Incidentally, it will be noted that A lies every time he makes the statement in the problem, so that it would appear to be impossible for B to deny that C declares that D lies—further evidence of artificiality.)

The "likelihood" I calculate as follows :

The probability that A tells the truth is $\frac{1}{3}$. Hence the probability that B denies that C declares that D lies is $\frac{1}{3}$.

If B denies that C declares that D lies, the probability that his denial is false (that is, that C does declare that D lies) is $\frac{2}{3}$. Hence the absolute probability that C declares that D lies is $\frac{1}{3}\times\frac{2}{3}=\frac{2}{9}$.

If C *does* declare that D lies, the probability that D tells the truth is $\frac{2}{3}$. Hence the absolute probability (that is, the 'likelihood') that D tells the truth is $\frac{2}{9}\times\frac{2}{3}=\frac{4}{27}$.

The 'probability', of course, is $\frac{1}{3}$.

[1] NATURE, **135**, 451, 1073 ; 1935. **136**, 301, Aug. 24 ; 1935.
[2] NATURE, **135**, 451 ; 1935.

News and Views

British Association : Officers and Meetings

AT the meeting at Norwich of the General Committee of the British Association, Sir Josiah Stamp, General Treasurer of the Association, was elected president for 1936. Sir Josiah, who is chairman of the London Midland and Scottish Railway, was president in 1930–32 of the Royal Statistical Society and enjoys an international reputation as an economist. The office of General Treasurer of the Association has been filled by the election of Prof. P. G. H. Boswell, until now one of the General Secretaries. Prof. F. J. M. Stratton, the other General Secretary, decided not to offer himself for re-election, so it became necessary to appoint two new general secretaries. These offices have been filled by the election of Mr. F. T. Brooks, reader in mycology in the University of Cambridge, and Prof. Alan Ferguson, assistant professor of physics at Queen Mary College, London. The new members of council are Lord Bledisloe, Prof. W. G. Fearnsides, Prof. Julian S. Huxley, Prof. R. Robinson, Dr. C. Tierney and Sir Gilbert Walker. Future meetings of the Association are announced for Blackpool (1936), Nottingham (1937), Cambridge (1938), Dundee (1939) and Australia (1940) ; and it is suggested that a selected party be sent in the winter of 1937–38 to take part in the jubilee meeting of the Indian Science Congress.

A Darwin Commemoration

SECTION D (Zoology) of the British Association devoted the afternoon of September 6 to the commemoration of the centenary of the landing of Charles Darwin on the Galapagos Islands, and of the birth of the hypothesis of the "Origin of Species". He landed on September 16, 1835, and during the five weeks he spent in the archipelago his observations included those on birds and reptiles recorded in his note-book, as quoted by Mrs. Barlow in her letter published in NATURE of September 7, p. 391. The clear differences presented more especially by the finches and the giant tortoises found on the different islands, led Darwin to a highly important line of thought and to the realisation that his facts, if well founded, "would undermine the stability of species". In an introductory address, Sir Edward Poulton gave an outline of the observations made by Darwin on the fauna of the islands, as a result of which he became convinced that he must abandon the idea of the separate creation of species though he was then unable to account for their origin. Sir Edward then reviewed evolutionary thought during the past century, especially in relation to the theory of natural selection. Prof. J. H. Ashworth gave an account of Darwin as a student in Edinburgh from 1825 until 1827 with particular reference to the development of his early taste for natural history and collecting, and concluded that in Edinburgh Darwin laid the foundation of his knowledge of the science of natural history. Prof. G. D. H. Carpenter spoke on Darwin and entomology, and cited examples in support of the theory of natural selection. Prof. E. W. MacBride spoke on Darwin and the problem of the population of the Galapagos Islands, and expressed his dissent from Sir Edward Poulton's views on the value of natural selection as a cause of evolution. Mr. H. W. Parker gave an account of the present distribution of the reptiles in the Islands, pointed out that two of the species found by Darwin were extinct and the others by no means common, and that the danger of extinction of other species had been recently realised by the Government of Ecuador. We hope shortly to publish an account of this interesting commemoration.