adapted eyes are more sensitive. This lessening of colour difference has a considerable effect in reducing contrast, as may be seen by viewing a sky with scattered broken cloud through a blue glass. Viewing through an orange or light-red glass increases contrast. With a deep-red glass, however, the discrimination factor may be raised and so again contrast difference is reduced.

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[1] Nutting, P. G., *Trans. Illum. Eng. Soc., N.Y.*, **11**, 939 (1916).
[2] Hecht, S., *J. Gen. Physiol.*, **11**, 255 (1928).
[3] Hewson, E. W., *Quart. J. Roy. Met. Soc.*, **69**, 47 (1943).

Causality or Indeterminism ?

IN *Nature* of November 25, Prof. E. T. Whittaker says "If a coin is tossed a thousand times and the number of occurrences of heads recorded, and if this experiment is repeated a very great number of times, there will be a statistical regularity in the records, which may be calculated by the ordinary theory of probability. Does the calculation . . . involve only the assumption (as regards the tossing) that there is symmetry in the system".

Does this not assume that the hand—or machine—which tosses the coin moves in a 'random' manner. Such an assumption is often made, and the result quoted as if it were an axiom. Is there, in fact, any scientific reason for it ? Would not the hand—or the machine tend to move in a systematic manner and thus produce a biased result if the action were repeated many thousands of times ? The assumption of symmetry appears to be a condition of the experiment yielding the hypothesized result ; it is clearly not justified by examination of the ordinary coin a human tosses—which is asymmetric—necessarily so if it is to achieve the purpose for which it is tossed.

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IN *Nature* of November 25 there is a letter from Mr. W. W. Barkas together with Prof. E. T. Whittaker's answer, concerning determinism. The reply refers *inter alia* to some experiment, which is apparently very famous, as during the last century nearly every book or treatise devoted to probability cites, describes or refers to, the so-called experiment of tossing a coin, or dice, etc. However, I have some doubts if any of the authors referring to this 'experiment' ever attempted to treat it as an experiment, that is, to repeat it.

As I have done so, although under somewhat improvised conditions, I would like to mention the results obtained, as they may be of interest to someone else.

I designed a simple device, by which the chosen coin, in fact, a new sixpenny piece, can be placed always in the same relation to the apparatus. A mechanically operated lever tosses the coin upwards a rather small distance with the same pressure exerted in the same period of time and on the same portion of coin, when tossed. The coin falls on a wooden surface covered with cloth, namely, an ordinary writing-desk. Before reaching the desk, the coin revolves several times in the air and after touching the surface it rebounds, as may be expected. The results : after tossing the coin a hundred times with head initially up, it rested with head up ninety-eight times. After adjusting the lever to a slightly different pressure exerted in the next hundred tossings, also with head initially up, the coin fell with head up once only.

I cannot say I was astonished, as I expected such a result, but it seems to me that it proves that the 'chance' of occurrence of head in tossing a coin is simply the result of the force applied, and consequently this experiment has nothing to do with indeterminism in the sense implied by Prof. Whittaker. On the contrary, as the two or one exceptions in position in which the coin falls are obviously caused by slightly uneven pressure (in force and duration) exerted by the rather improvised device, the experiment, after being repeated under strictly controlled conditions, is more likely to be used by advocates of determinism.

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MR. BARKAS in his letter in *Nature* of November 25 says, "My difficulty is that if the final result of, say, one million, or billion, photons is regular (that is, determined), then how can the choice of any . . . be individually indeterminate". I should like to point out that the final result is not strictly regular or determined. With increasing numbers of photons, the fluctuations about the mean become less and less proportionally significant, until, for many purposes, they can be left out of account. The same is true of the pressure of a gas. If we calculate the pressure from observations on a surface sufficiently large, then the fluctuations may be altogether inconsiderable and the pressure can be regarded as constant ; but if we take a surface sufficiently small—say, for example, a smoke particle—then the fluctuations will be large and will be the origin of the characteristic Brownian movement.

I should like to point out further that the argument Mr. Barkas quotes from the Guthrie Lecture cannot be sustained as disproving causality. What, under certain conditions, it does show is that causality fails if parameters are restricted to photons. Clearly, however, in the passage of photons through Iceland spar, parameters associated with the crystal lattice must be taken into account, and when this is done, the argument fails. Apparently von Neumann's argument has a similar weakness[1].

A large number of the facts of modern physics can be unified by means of non-causal laws ; but no case, so far as I know, has yet occurred where causal explanations can be ruled out as impossible. Natural phenomena, as we see them, may indeed permit of unifying descriptions from two totally different points of view. Perhaps, alas, both types of description may fail.

Determinism is probably not applicable outside material phenomena, but in regard to these it has proved a very useful philosophical principle for hundreds of years. Caution is therefore necessary before it is thought of as having 'collapsed'.

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[1] Pelzer, *Proc. Phys. Soc.*, **56**, 195 (1944).