expect them to be direct within the limits of the navigational mechanism. The data on such flights are fragmentary, for it is seldom that the exact times of departure and arrival can be determined; but many long oceanic flights seem to be made at speeds considerably above the trifling rates generally found in homing tests, which may be construed as added support for the distinction between homing and migration.

Rowan's (*Trans. roy. Soc. Canad.*, 3rd Ser., Sec. V, 1946, 123–125) test with American crows from Edmonton, released 720 miles to the east, at Portage la Prairie, and Rüppell's (*J. Orn. Lpz.*, 1944, **92**, 106–132) later work in Europe with the hooded crow indicate that in these species the inherited tendency is to fly a particular compass course or series of courses and not merely to fly to a particular point. It is unfortunate that in this particular test of Rowan's the returns were so low. If they had been more numerous, the test might have finally disposed of the hypothesis that migrating birds orient themselves by sensitivity to the earth's magnetic field; for the angle that Edmonton and Portage subtend to the magnetic north pole is quite large, and any orientation of the birds dependent on the magnetic field should presumably have been appreciably different at the two places. Ising's (*Arch. Math., Astron., Fys.*, 1946, **32A**, No. 18) suggestion that the navigational mechanism in migration may be explained by sensitivity to the effects of the Coriolis force on the semicircular canals of the inner ear has at least a sound theoretical basis, but Thorpe and Wilkinson (*Nature, Lond.*, 1946, **158**, 903–904) have shown that there are serious practical difficulties to be overcome before such an explanation can be accepted.

It is likely that the lack of an acceptable explanation of migratory navigation has tempted some workers to ascribe it to reaction to the prevailing wind or to visible aids such as landmarks or the direction of the sun. The inherited tendency in many migrants is certainly remarkable, though perhaps not more so than the habit of building a particular form of nest, but it seems beyond belief that it should enable an unaccompanied young bird to make use of landmarks; and the crow experiments cited above show that this explanation is inapplicable to these birds. Long periods of unbroken overcast over many areas of ocean and the extreme variations in wind speed and direction over short periods make it inconceivable that these factors could provide the basis for the astonishingly precise landfalls made by numbers of oceanic birds in particular. It is possible that no single mechanism will be found to be generally applicable, but I feel that Ising's hypothesis merits the most careful examination because it seems to be the only one capable of explaining a large number of cases. In the meantime, much may be learned from the observational approach. If some transoceanic migrant could be followed by airplane or radar from the start of its flight, we would at least learn whether it starts on course and would accumulate sorely needed information on the speeds maintained on such flights. The golden plover, in its autumn migration, flies from Nova Scotia to Brazil, often apparently without sighting land; and it is possible that it may continue on across the Brazilian jungle without a halt until it reaches open country. If some of the spectacular migration flights such as this could be followed for even the first few hundred miles, we would add greatly to our inadequate knowledge of them.

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Physical Basis of Bird Navigation

A paper by H. L. Yeagley (*J. appl. Phys.*, 1947, **18**, 1035) on the above subject describing experiments with homing pigeons is a stimulating and provocative contribution to a little understood phenomenon of nature. It has already given rise to three rejoinders by physicists (J. Slepian. *J. appl. Phys.*, 1948, **19**, 306; R. H. Varian. *J. appl. Phys.*, 1948, **19**, 306; L. Davis. *J. appl. Phys.*, 1948, **19**, 307).

I write mainly on the question as to whether birds are sensitive to magnetic fields and to their gradients. During the war the sweeping of magnetic mines called for the setting up of intense magnetic fields over a considerable area. Elementary calculations show that these fields far exceed in magnitude those which would be met with under ordinary conditions. The same is true of the gradients of the fields. Moreover, these fields extend to considerable distances below and above the surface of the sea. The complete absence of any effect on fish and on birds was apparent to everyone who had to deal with minesweeping.

If birds were guided in their navigation by geomagnetic phenomena, it would be expected that their behavior would be affected when they flew within several hundred yards of minesweepers. Yet nothing of the sort has so far been observed with such migratory birds as herring gulls and ducks or with nonmigratory birds. In many of the sweeping areas birds were rare, even though sullage was thrown out. When present, birds appeared to be supremely indifferent to magnetic fields, even at the sudden beginning of magnetic pulsing. A sweeper might pass close to a group of gulls or ducks sitting quietly on the water, yet they would completely ignore any surprise which man might provide except for food. Again, a flight of ducks might pass over the sweep with no sign of tailspin!

The hypothesis that electromotive forces set up in the body of a bird by flying through a magnetic field would excite some sensory mechanism which would help the bird in navigation does not seem plausible in view of the great variation of electric fields existing in the atmosphere. Again, the effects of the earth's rotation as manifested by the Coriolis force are small compared with gravity but still large enough to be given consideration. However, the requirements of level flying on the part of the bird seem to be excessive if the earth's rotation is to play a part in bird navigation.

The only other explanation within the ken of physicists seems to be along the lines of such things as the elevation of the sun, the stars, and the use of prevailing winds. The eyesight of birds is known to be greater than that

of men, and it is possible that even in daylight the stars may be an aid. Also, their sense of terrain is probably better than that of all save the most experienced humans. There seems to be little reason to throw overboard the simple elements of navigation which are already known.

It is well to consider the opinions of experienced biologists and physiologists and to reflect on how much is taken for granted which has not been confirmed by facts. A recent paper by Griffin and Hock (*Science*, April 2, pp. 347–349) gives results of observations from an airplane on the flight of gannets released from a point over 200 miles inland from their nests near Gaspé, P. Q., and over 100 miles from the nearest salt water. The observed flight paths spread out from the release point in what appeared to be random directions, and the results suggest that the gannets were exploring until they could pick up a familiar coastline on the west side of the Gulf of St. Lawrence. When it comes to migratory flights at the appointed season, there comes to mind the fall flight of woodcocks, which crowd into the western part of Nova Scotia before taking off over the Bay of Fundy to New England on a flight of some 200 miles. Still more remarkable are the migrations of hummingbirds, possibly over the same route. In both cases nothing is apparently known as to the directness of their flight over a long sea distance. More facts are obviously needed. From Dr. Yeagley's curves showing the geomagnetic and geographical latitudes over the North American Continent, it is tempting to assume that the well-known migratory paths of geese, brant, and ducks in the East and in the West follow lines along which the two latitudes cut at the greatest angle. Here again an alternative and simpler explanation lies in topographical recognition. If scientists are to avoid taking refuge in the term "instinct" as a way of saying that they do not know, it is clear that more experimental evidence is needed.

I wish to express my grateful thanks to Ralph M. Meredith and to Harold Beament for helpful discussion and letters. Both served as Commanding Officers of HMC Minesweepers during the war, and their accumulated experience has been of great help. I also wish to thank Capt. A. F. Peers, RCN, for his kindly aid and advice.

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Microbiological Assay or Bacterimetry?

Within the last few years there has originated a new branch of analytical chemistry generally referred to as "microbiological assay" or "microbioassay." With regard to convenience and descriptiveness, these terms seem poorly suited. Through long usage the parent term "biological assay" has been linked to the concepts of drug and potency and tends toward a semiquantitative connotation. According to Hackh (*Chemical dictionary*, 1944), biological assay is "the determination of the active principles of a drug by determining the smallest quantity which will produce certain symptoms in animals," and a similar definition is found in the 1946 edition of Webster's dictionary. This definition, modified in accordance with the prefix micro-, seems hardly adequate to cover a system of methods which, in principle, can determine any substance affecting the growth of a microorganism as a nutrient or otherwise, and which already today, at an early developmental stage, does so in selected cases with an accuracy superior to that of nonbiological methods. In writing and speaking, the current terms are cumbersome, because of length and lack of flexibility in the formation of adjectives or adverbs. It would seem from more than one point of view that a simpler term, and one that is not encumbered by pre-empted connotations, would fill a need. Perhaps even a family of terms, to cover both the general and the specific aspects of the new field, would be useful.

Established branches of analytical chemistry are gravimetry, colorimetry, acidimetry, oxidimetry, iodimetry, etc. Many other analogous terms have gained usage, e.g. calorimetry, chlorimetry, fluorimetry, polarimetry, turbidimetry, or amperometry, conductometry, dilatometry, or manometry. The choice between the -imetry and -ometry endings seems to be fluid in many cases (iodimetry and iodometry, saccharimetry and saccharometry, etc.), while in other instances it seems to be based on etymology (conductometry, dilatometry, spectrometry) or perhaps euphony. However, a tendency, as yet uncodified, seems to exist to use the two endings for purposes of distinction, *i.e.* an "-ometer" seems to be preferentially an instrument for the determination of a property or substance, the corresponding "-ometry" being devoted to these measurements in their own right, while an "-imeter" and "-imetry" deal with a property merely as a means to a general analytical end. Perhaps "saccharometry" and "colorimetry" serve well to exemplify this distinction. It may serve the ends of clarity and consistency to follow the existing trend, in giving preference to the "-imeter" and "-imetry" endings in connection with the analytical *tool*. As to possible conflicting claims of etymology and systematics, the latter have often before been given preference in matters of chemical terminology.

The writer would like to propose the term "bacterimetry," analogous to gravimetry, colorimetry, etc., to replace "bacterial microbiological assay." Most of the microbiological analytical methods now in use employ bacteria. If, in the future, methods based on true fungi or protozoa should be broadly developed, "fungimetry" and "protozoimetry" may be added to the practical biochemical dictionary. As a more comprehensive term for the new branch of analytical chemistry, "bionimetry" or "biotimetry" may be considered, the writer tending to prefer the former because of its placing the accent on the means of analysis (bions) rather than on its objects (biotics). In line with the suggested considerations, "isotopimetry" could serve to label another newcomer in analytical chemistry, viz., the isotope dilution method. Growth in science demands a growing vocabulary.

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