non-specifically bound. This is confirmed by our unpublished work in which we failed to demonstrate labelling of the plasma protein fractions after incubation with sulphur-35 labelled sulphate.

Plasma proteins contain functional SS groups and SH groups which are probably part of the cystine and cysteine molecules. Although there is little evidence to suggest that animal tissues can synthesize sulphur-containing amino-acids, there is good evidence that it does occur in animals and that this requires the presence of micro-organisms in the alimentary tract[9]. The steps whereby the sulphur-35 of labelled sodium sulphate becomes incorporated into the sulphur-containing amino-acids of human plasma proteins are yet to be elucidated. This investigation demonstrates that it does occur. It is possible that in the human, as in lower animals, the activity of intestinal micro-organisms plays an important part. However, in the present work, one must postulate initial secretion of labelled sulphate into the bowel, directly or via bile, because all doses were given intravenously. The rapidity with which the incorporation of the inorganic sulphate into plasma protein occurs suggests that an alternative metabolic pathway may exist.

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BIOLOGY

Sun Navigation by Birds

C. J. PENNYCUICK[1], discussing the physical possibility of an estimate of the change in azimuth of a celestial object by a bird, says: "Birds very often fly round in circles whilst orienting, and therefore cannot have their eyes stabilized in azimuth. The change in azimuth can therefore be measured only by reference to a fixed object [*sic*], when the bird is stationary on the ground. Over the sea it is not physically possible to measure it at all without some kind of compass. However, birds do navigate over the sea. Hence Matthews' hypothesis as it stands is untenable". Again in his summary: "Matthews' hypothesis . . . is rejected on the grounds of physical impossibility of making one of the measurements,. . .".

Assertions about the physical impossibility of animal activities have so often proved false that they should be closely scrutinized, and Pennycuick's argument appears to be fallacious. What the bird needs is not a fixed object (in parenthesis it may be pointed out that a compass needle is not a fixed object) but an indication of a direction—any direction—in the horizontal plane lasting long enough (not more than a few minutes on Matthews's[2] hypothesis) to allow the change of azimuth of the celestial object to be measured. My experience of flying at a moderate height over the open sea is strictly limited; but I have never known an occasion when the sea could not be seen at all and when the necessary stable indication of direction could not have been obtained from the pattern of waves on its surface; in the belief that occasions when this indication is not available are exceedingly rare, I am confirmed by an experienced pilot of aircraft. It is therefore fair to assume that a flying bird could always obtain the necessary information in flight over the sea and that Matthews's hypothesis has not, on this ground, been invalidated.

Pennycuick's own hypothesis, requiring only an appreciation of the Sun's elevation and of its rate of change, is attractive and economical, but it is surely unlikely that a bird should neglect information about the sign and magnitude of the Sun's rate of change of azimuth when this information, always available, could be used to increase the accuracy of estimate of its own position and to eliminate the ambiguity which can arise, according to Pennycuick, in certain circumstances.

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IT must be conceded that the rate of change of the Sun's azimuth could, in principle, be measured by reference to the orientation of the waves on the sea, but the possibility of using this method for navigation requires closer scrutiny. If it be assumed that the bird can use the maximum accuracy available, the problem falls into three parts:

(1) Within what limits can the direction of the waves be defined?

(2) Within what limits may its rate of change be deemed to be zero?

(3) To what distance on the ground does the minimum detectable change of rate of change of azimuth correspond?

It is to be hoped that someone better qualified than I will be able to produce definite information on the first two questions, but meanwhile some reasonable surmises may be made.

(1) The meaning of the "direction of orientation" of the pattern of waves on the sea would appear to be statistical in nature, the accuracy with which it could be defined increasing with the number of waves visible. The direction of the waves on a large stretch of sea seen from the air could clearly be defined within 10°, and probably usually within 1°. Whether it could be defined within 0·1° (1/5 of the diameter of the Sun's disk) is not so clear. In the following argument ± 0·01° accuracy will be assumed, which is perhaps optimistic.

Large errors would occur in shallow waters owing to refraction of the waves in water of varying depth, so the use of the method would probably be confined to the open ocean.