ANIMAL NAVIGATION

Constant compass calibration

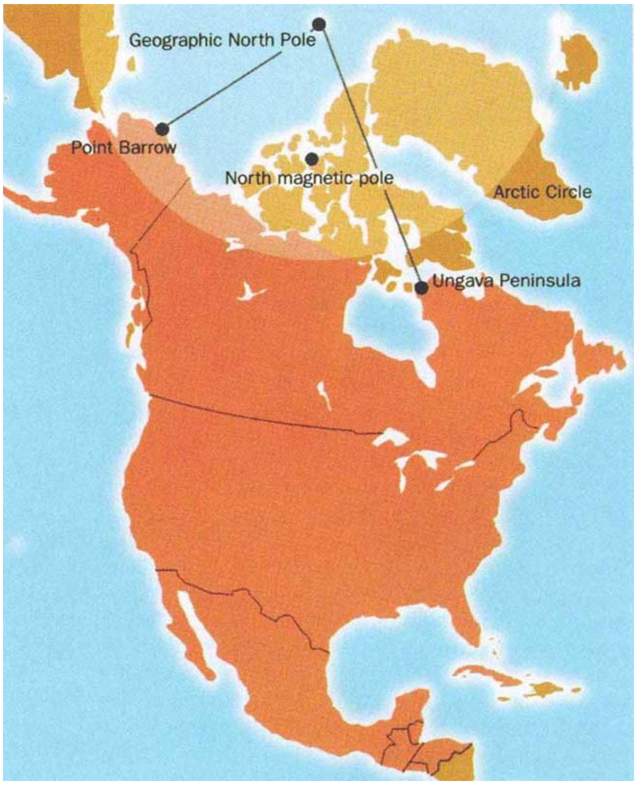
James L. Gould

MIGRATING birds have an embarrassing number of compasses, which they calibrate against one another early in life. But the original calibration of the magnetic compass becomes dangerously inaccurate as birds migrate between high and low latitudes. Now, as described on page 230 of this issue[1], Kenneth P. and Mary A. Able have discovered how birds resolve the potentially fatal problem of shifting declinations, and remind us once again how well oiled the machinery of navigation is.

The Ables studied Savannah sparrows, a species that migrates from above the Arctic Circle in Canada to as far south as Central America. Like most migrants, the sparrows fly mainly near dusk or at night; this is probably a good way to avoid overheating and predation. And, like most migrants, they are born with two preprogrammed default directions for migrating. One is magnetic, the other celestial. This redundancy is important because though celestial cues can be very precise, they are unavailable when the sky is overcast.

The young sparrow is presented with two problems. The first is to calibrate its celestial vector against the dusk and night skies. The key factor here is to find true north, which they do over the course of several days by determining the axis of rotation of celestial cues — the pole point in the sky. The rotating cues include the pattern of polarized light in the sky (especially prominent at dusk) and the pattern of stars at night. By itself, however, determining true north from celestial rotation is of limited value. To use either star or polarization patterns under real-world conditions — that is, when clouds may obscure much of the sky — the bird must be able to infer true north from a partial view of the pattern. But because the positions of these patterns change over the course of the evening as the Earth turns, the bird must use its internal clock to calibrate the calibration.

The second problem is more difficult. True north and magnetic north can differ by as much as 90°, especially at high latitudes (see figure). This declination arises because the north magnetic pole is inconveniently located near Bathurst Island in northern Canada, some 1,600 km from the geographic North Pole. For young Savannah sparrows born near Point Barrow in Alaska, therefore, magnetic north is almost 90° east of true north. Chicks born to parents nesting on the Ungava Peninsula, in northern Quebec at the northeastern mouth of Hudson's Bay, are exposed to an opposite declination — nearly 45° west. So the innate magnetic vector in sparrows must be reoriented by as much as 90° to compensate for the natal declination. Accordingly, young birds calibrate their magnetic compass against the celestial pole — true north. At this point, all three compasses are aligned.



Map showing the range of the Savannah sparrow (red), also indicating why a bird's innate magnetic vector must be reoriented by as much as 90° to compensate for the natal declination.

Finally, the birds need to recalibrate their celestial compasses and magnetic compass as they grow older and begin to migrate. Why is this later round of recalibration necessary? Consider the celestial cues they are using. As migrants travel south, new star patterns appear over the horizon; the same is true as the seasons change, and new constellations become visible at night. At the same time, the changing day length as the seasons pass alters the relationship between celestial cues (star and polarization patterns), direction and time of day.

To continue using celestial cues, then, the birds must recalibrate these patterns periodically. In theory, this recalibration could be done against celestial rotation (as it was initially) or against the magnetic compass. Received wisdom, based on laboratory experiments subjecting migrants to conflicts between magnetic and celestial cues, indicated that nearly all birds are programmed to opt for the second alternative[2]. This suggested to most of us that migrants do not have the leisure to redetermine the axis of celestial rotation *en route*. They must rely on theoretically instantaneous recalibration to magnetic cues.

But as a Savannah sparrow migrates south, it is not just celestial cues that change: the declination shifts inexorably towards 0° as birds leave their nesting areas and move through Canada and the United States. Thus, to rely on magnetic cues at all after leaving the natal grounds seems foolish, and recalibrating celestial cues on the basis of an increasingly mistaken declination value ought to compound the problem.

The Ables wondered if the necessarily artificial conditions and short-term experiments used to test for recalibration might be obscuring some other, more sensible mechanism. They tried a more naturalistic approach, mimicking the rest stops many long-distance migrants make to feed and recover during their arduous travels. By giving the sparrows several days to deal with the changing relationship between celestial and magnetic cues, the Ables found that the birds *will* take the time to redetermine the celestial pole point. In the face of a serious discrepancy between celestial and magnetic cues, they recalibrate the magnetic compass accordingly. Apparently the opposite happens when the birds are given only a day or two to resolve the discrepancy — under these rushed circumstances, the celestial compasses are reset to the magnetic compass.

It is a relief finally to see the full picture of the innately orchestrated compass-calibration strategy emerge. Now we can understand how sparrows have been managing to do so much better in their migration flights than our models used to allow them to do. □

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1. Able, K. P. & Able, M. A. *Nature* **375**, 230–232 (1995).
2. Able, K. P. in *Orientation in Birds* (ed. Berthold, P.) 166–179 (Birkhauser, Basel, 1991).