ORIENTATION AND NAVIGATION IN VERTEBRATES pdf

1: Magnetoreception - Wikipedia

This book reviews all major models and hypotheses concerning the mechanisms supposed to underlie the process of navigation in vertebrates. It covers data on all major model groups of vertebrates studied in the context of animal navigation, such as migratory birds, homing pigeons, sea turtles, subterranean mammals and some migratory fish species.

Lost in migration True navigation Birds may be able to use any or all of the compass mechanisms just described, but a compass is useful for reaching a specific location or goal, such as a nest site, food cache, wintering area or breeding territory, only if a bird also knows its current location. With the exception of birds transported to previously unknown locations so investigators can study their navigational abilities, birds can acquire map information about their surroundings. In areas a bird is familiar with, such as a breeding territory, map information can be based on visual landmarks as well as local magnetic, auditory, and olfactory cues. Several species of birds, including homing pigeons and birds that regularly store and retrieve food from caches, are known to use of landmarks to locate specific, previously visited sites. Homing pigeons use other cues to identify the general location of their home loft or other goal, but the final step in the process of homing appears to involve the visual recognition of landmarks Gagliardo et al. Birds could also potentially navigate using a process called path integration sometimes referred to as dead reckoning. Path integration is a navigational, or homing, strategy used by many animals, ranging from arthropods to mammals. Using path integration, an animal is able to return to a specific location after travelling to any point some distance from it, even if the path taken is circuitous, by using information collected during the journey to determine a direct straight-line route back. Using path integration, an animal determines its position and the positions of other objects in the environment by integrating the distance and directions travelled during a journey. Distance and direction information can potentially be obtained from a number of sources, including proprioceptive cues, vestibular or somatosensory cues, and solar and magnetic cues. Among birds, Wiltschko and Wiltschko suggested that young pigeons use path integration or, using their terminology, route reversal when initially learning about their environment until they are about three months old. However, because the likelihood of errors increases with increasing distance Able , path integration, if used by birds, is likely of greater importance for short-distance navigation. Landmarks may be useful for short-range homing returning to a familiar area or site , but how do birds located at greater distances from a target destination determine where they are located? The short answer is that we do not know. The possible importance of olfactory cues in bird navigation has only been examined in two species. However, Jorge et al. One possible exception, however, may be the tube-nosed seabirds order Procellariiformes. These seabirds have large olfactory bulbs and a well-developed sense of smell. Experiments have revealed, for example, that Antarctic Prions Pachyptila desolata can detect dimethyl sulfide DMS at very low concentrations Nevitt and Bonadonna In the marine environment, DMS is known to be associated with the abundance of phytoplankton that is in turn associated with predictable oceanic features Nevitt ; Figure Although clear-cut evidence is lacking, olfactory cues, such as DMS, might be used to generate olfactory maps that could be used for navigation by tube-nosed seabirds. Dimethyl sulfide emissions increase over ocean waters where phytoplankton are plentiful e. Such emissions are often predictably present at certain locations and these locations may provide tube-nosed seabirds with navigational guideposts From: Infrasounds are sound waves with frequencies below about 15 to 20 Hz, the lower threshold of sound detection by humans. Higher-frequency sounds tend to be attenuated by the atmosphere, but infrasounds can travel many thousands of kilometers. Persistent infrasounds are generated by mountain winds and ocean waves Hagstrum , and laboratory tests indicate that some birds, including pigeons Kreithen and Quine and Helmeted Guineafowl Numida meleagris; Theurich et al. However, other species of birds are apparently unable to detect infrasounds Beason and, for the vast majority of bird species, the ability to detect infrasounds has not been tested. In addition to questions concerning how many species can detect ultrasounds, Bingman and Cheng also point out that the assumed primary sources of infrasounds for birds, mountain winds and ocean waves, are not point sources. In other words, a bird capable of hearing infrasounds and migrating, for example, through the central United States would potentially hear those sounds being emitted from oceans on the east, west, and Gulf coasts and from the entire length of the Rocky and Appalachian mountain chains. Humans navigate using a bi-coordinate system. Determine your latitude and longitude easily accomplished with a GPS unit and you know exactly where you are located. Based on our knowledge to date, it seems likely that avian navigation is also based on a bi-coordinate system but it could very well be multi-coordinate; Thorup and Holland If so, navigating birds need some way to discern two coordinates likely corresponding to our latitude and longitude. Birds can potentially determine their location along one coordinate latitude using two magnetic cues: These species, and almost certainly many others, have magnetic iron-oxide particles particles in their heads and, specifically, in certain neurons , primarily in the upper beak. Electrophysiological recordings from associated nerves Semm and Beason and the results of several behavioral studies e. The iron oxide particles in the beak of birds come in different forms Figure Tiny flattened structures called platelets consisting of a ferromagnetic mineral called maghemite form straight chains that are aligned along the dendrites of a neuron. The chain of maghemite platelets attracts a cluster of magnetite particles that are connected to the nerve cell membrane. Each dendrite senses only one direction of the magnetic field Fleissner et al. Changes in the direction and strength of the magnetic field cause ion channels associated with the magnetoreceptors to open or close Figure 18 , and the resulting nervous impulses provide birds with information about the magnetic field. Because of the differing alignments of the dendrites, these receptors appear to act as a three-axis magnetometer, allowing birds to sense both magnetic field duration and the strength or intensity of the magnetic field Fleissner et al. Magnetoreceptors in the bill of a homing pigeon. A Pigeon head showing location of nerves in the upper beak thought to play a role in magnetoreception. B The upper beaked viewed from below showing the location the six white spots of iron oxide particles. C Diagram of the end of a neuron dendrite containing a non-magnetic vesicle, several clusters of magnetite crystals, and chains of iron-bearing platelets From: Possible magnetic sensors based on magnetite particles. Top, A chain of magnetite crystals is attached by protein strands to ion channels in a nerve cell membrane. Ion channels open, causing nervous impulses, and close in response to the magnetic field indicated by the arrow. Below, Vesicles black circles filled with magnetite particles are attached to a membrane by protein strands and, in response to the external magnetic field arrow, B the vesicles move towards each other, deforming the membrane, opening the ion channels, and triggering a nervous impulse From: If their magnetic receptors provide information about the inclination the light-based receptor , strength, and direction of magnetic fields, how might birds use that information to generate grid-based navigational maps? A grid-based navigational map requires that birds determine both their latitudinal and longitudinal position. Latitude can be determined using the inclination and, perhaps, the strength of the magnetic field. In some locations, lines of equal inclination and lines of equal strength are nearly parallel and oriented in an east-west direction, potentially allowing birds to determine latitude using either or both cue s. However, in other locations, lines of equal inclination and lines of equal strength are not parallel and lines of equal strength are not oriented in an east-west direction. In such areas, the two sources of magnetic information might provide birds with information about both their latitude and longitude or, in other words, a bi-coordinate magnetic map. One area where the lines of equal magnetic inclination and lines of equal magnetic strength or intensity vary in direction to form a grid-like pattern is northwestern Russia. The warblers corrected for the displacement by shifting their orientation from the northeast at the capture site that would take them to their breeding ground to the northwest after the displacement Figure below. Such results indicate that the warblers were somehow able to determine that a longitudinal shift had occurred and were able to correctly orient in the direction that would take them to their breeding areas. Because lines of equal inclination and strength form a grid-like pattern in the study area, the warblers may have used those cues to accurately determine their position and then orient in the direction that would take them to their breeding areas. Isolines of magnetic intensity solid thin lines and inclination dashed lines relative to capture Rybachy, Kaliningrad region and displacement Zvenigorod, Moscow region sites and the breeding range of Eurasian Reed Warblers in the region shaded light gray. Solid arrow shows the displacement direction. A number of studies have revealed that birds have an innate ability to use their inclination compass; no experience is needed. However, using variation in magnetic strength to navigate requires experience because lines of equal magnetic strength vary in their orientation in different areas and, therefore, birds must learn the pattern of variation in the areas they occur. One possible illustration of this comes from the results of a study of White-crowned Sparrows Thorup et al. One explanation for such results is that the adult sparrows had acquired the needed magnetic information during previous migratory journeys, whereas juveniles had not. In some areas, such as the United States Figure 20 , the lines of equal magnetic inclination and field strength are parallel, or very nearly so, and do not form a grid-like pattern and, therefore, may not, in combination, be useful for navigation. Isolines of magnetic field elements in North America. A Isoclinics isolines of magnetic field inclination. B Isodynamics isolines of total field intensity. Adjacent isolines represent differences in intensity of 1, nT From: For example, some investigators have noted that magnetic intensity exhibits gradients i. The field present at each location on Earth can be described in terms of a total field intensity and an inclination angle. Total intensity has two vector components: Horizontal field intensity is greatest at the magnetic equator where horizontal field intensity equals total field intensity and is lowest at the magnetic poles where horizontal field intensity is zero ; the reverse is true for vertical field intensity. Few investigators have examined the possibility that birds might use these gradients for navigational purposes. However, Dennis et al. Using flight trajectories recorded by GPS-based tracking devices, they found that many of the pigeons released at unfamiliar sites initially flew, sometimes several kilometers, in directions that were either parallel or perpendicular to the bearing of the local intensity field Figure Pigeons exhibited this behavior regardless of the bearing of their home loft and significantly more often than would be expected by chance. Pigeons took longer than normal to decide which direction to finally orient termed the vanishing interval in homing pigeon research. Because other orientation cues are not affected by magnetic anomalies i. However, in contrast to Dennis et al. Examples of the orientation of flight trajectories of homing pigeons relative to isopleths of geomagnetic intensity. Single-color lines and points indicate flight trajectories and position fixes of individual pigeons. Yellow circles show the location of release sites, and yellow lines designate the straight-line direction to the home loft. Thin green lines are magnetic intensity isopleths 10 nT intervals. Background color depicts relative elevation low-elevation areas are blue and high-elevation areas are green. Red scale bars are m. Arrows indicate locations of alignment of individual birds: Detailed views of examples of parallel and perpendicular alignments From: Both young and adult White-crowned Sparrows were captured on their breeding area in the Northwest Territories, Canada, towards the end of the breeding season and shortly before they would normally begin fall migration 15 July to 10 August. One group of sparrows 15 adults and 15 juveniles were transported on an icebreaker to unfamiliar sites along a northeasterly route to the magnetic north pole A control group 5 adults and 39 juveniles was transported a short distance west of the capture site. Using Emlen funnels Figure 6 above , the directional orientation of both groups of sparrows was determined, with the experimental group tested at nine different locations including their breeding area; site 1 in the Figure 23B. Sparrows in the control group generally oriented to the southeast Figure 24 , the general direction of their presumed wintering area. Sparrows being transported to the east, however, shifted their orientation from their normal migratory direction to a direction leading back to the breeding area or their typical migration route, suggesting compensation for the west-to-east displacement using geomagnetic cues perhaps in combination with solar cues. One possible cue used by the sparrows is geomagnetic declination the angle formed by the difference between geographic and magnetic north. The White-crowned Sparrows could have used the stars to determine geographic north i. Determining the exact angle of declination at high latitudes is likely difficult because of the steep geomagnetic field lines, but recognizing a positive versus a negative declination would be easier.

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