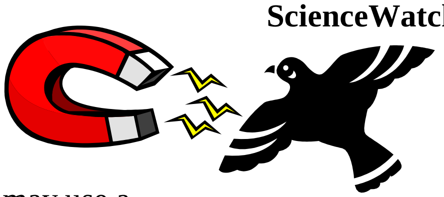
ScienceWatch-The Sixth Sense of Homing Pigeons



For many animals, especially migrating birds, knowing precisely where you are can be a life or death matter. So it is no wonder that animals have several mechanisms by which they navigate. They may use a compass based on the stars or sun or they may use landscape cues to guide them. Scientists have long suspected that birds and other animals are also able to navigate by sensing the earth's magnetic field. For example, placing subjects in artificial magnetic fields will cause them to change their flight path or direction of movement, indicating that organisms as diverse as bacteria, butterflies, turtles and mole rats have an ability to sense the earth's magnetic field (see – *Animal Magnetism*, ScienceWatch, November 2001 or www.HRAS.org). However, the anatomical and physiological basis for this magnetic sense has remained a mystery—that is until now.

Writing in the August 2007 issue of the journal *Naturwisseschaften*, Gerte Fleissner and her colleagues at the University of Frankfurt, Germany, show that the skin surrounding the upper beak of homing pigeons (*Columbia livia*) contains heretofore unknown organs, special dermal receptors that provide the birds with a magnetic sense. Using powerful electron microscopes, coupled with x-ray analysis, the team could see the nerve cell receptors as well as sub-cellular structures associated with them. The receptors are composed of six clusters of nerve endings, three on either side of the beak. The nerve endings of a cluster on one side are aligned in one of three spatial directions: head to tail, left to right, back to belly. The three clusters on the other side repeat the pattern, forming a pair of clusters for each direction. What makes these receptors specially adapted for magnetoreception is that they contain two kinds of magnetic iron oxides. One, hematite, is present in tiny "iron bullets", 10-15 elongated particles, attached to the inside of each nerve cell membrane. The second, maghemite, occurs in tiny square-shaped "platelets" arranged in bands within each nerve cell. Additional maghemite also appears as a coating on tiny sacs or "vesicles" within the nerve cells.

Certain bacterial cells also contain magnetic sub-cellular particles called "magnetosomes", which allow them to distinguish up from down. The bacterial magnetosomes are made up of tiny chains of magnetic crystals, which line up in a magnetic field, acting like the needle of a compass. But exactly how do the clusters of nerve cells in homing pigeons with their intricate arrangement of sub-cellular particles allow them to navigate? Fleissner *et al*. think they have the answer.

Since the nerve fibers of each of the three pairs of clusters are aligned in a particular direction, Fleissner suggests the alignment allows the birds to sense north from south, east from west and up from down simultaneously. Furthermore, she says, each of the three sub-cellular structures has a specific function. The maghemite-coated vesicles act to concentrate the magnetic flux. This causes the bands of platelets to line up in a particular orientation and attract the iron bullets. It is the movement of the bullets at the nerve cell membrane that stimulates the receptors and, since the receptors in each pair of

clusters is tuned in to a different component of the earth's magnetic field, each will be stimulated differently. By synthesizing the information coming from all three pairs of receptors, homing pigeons know exactly where they are at any given moment.

In mole rats, which are essentially blind, magnetoinformation appears to be processed in an area of the brain known as the superior colliculus. Exactly how birds coordinate magneto-derived information with celestial and landscape cues, and where it occurs in the brain has yet to be elucidated. Hinting that magnetoreceptor organs may be universal in birds, the authors say they have found similar structures in the upper beak skin of birds as diverse as robins, warblers and chickens. It is likely that different species use one or another navigation mechanism depending on the circumstances.

For homing pigeons, the earth's magnetic field may be sufficient to guide them over long distances. Other birds may need to reset their compass by observing the sun as they travel. Certainly bird brains, even those of pigeons, are not as simple as we think.

Saul Scheinbach