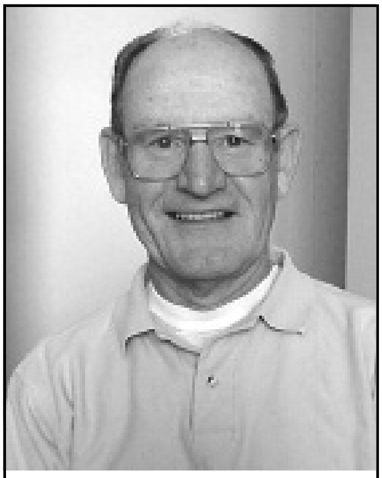
Navigation & Homing

IN PIGEONS: A BRIEF SKETCH



Gordon A. Chalmers, DVM
Lethbridge, Alberta, Canada
Email: gacdvm@telus.net

Navigation and homing in pigeons and migratory birds continue to be fascinating yet puzzling subjects. Although many strides have been made over a number of years in understanding some of the complexities associated with this subject, much remains a mystery to this day. Even so, modern research continues to peel away the layers—albeit slowly—surrounding this mystery. The following information discusses some of the currently available knowledge on the multifaceted subject of navigation in pigeons and other birds.

There seems to be general support for the idea that pigeons use a two-step method to home accurately: firstly, a map to determine their home direction and secondly, a compass to guide them.

It is known that presence of the sun (sun compass) allows pigeons to navigate correctly. It seems that they are able to compensate for the movement of the sun across the sky and hence, to stay on course. However, finding the home direction doesn't require a view of the sun. In order to navigate in the absence of sun on cloudy days, the birds appear to use cues from the lines of magnetic force that run from pole to pole over the entire earth. The belief is that pigeons, like other birds, have an inborn magnetic sense that they use as a directional compass.

The liquid core of the earth produces a magnetic field that is a dipole (di = two) field in which the magnetic poles lie near the geographic north and south poles. The field lines of the magnetic field leave the ground at the Antarctic pole, curve around the earth and then re-enter the earth at the Arctic pole. Magnetic north and geographic north differ by a certain number of degrees. This variation or deviation may be considerable near the magnetic poles but it soon becomes much less at lower latitudes. In most parts of the world the field lines run roughly north-south. The total intensity of the field decreases gradually from very high values at the poles to about half that strength near the magnetic equator.

Superimposed on this general pattern are certain irregularities. For instance different degrees of magnetization of rocks cause localized magnetic anomalies; as well, time variations of the geomagnetic field occur on a daily basis. These regular daily variations plus the irregular fluctuations that occur because of magnetic storms from space, etc., are important in consideration of a navigational map used by birds. Because of its structure, the magnetic field is present at all times, and therefore, is a constant, reliable source of information. The magnetic field seems to provide directional information for birds, and factors such as its total intensity and inclination may provide birds with information about their geographical position.

The use of magnetic information in the orientation of birds was discussed as early as the 1800s. As long ago as 1859, one German researcher proposed what we now call a magnetic compass in birds. The magnetic compass was described first in the European robin, a small bird that migrates at night, and experimental work showed that these birds use the magnetic field in direction finding. The magnetic compass of birds is what is known as an inclination compass – instead of indicating north and south it distinguishes between poleward and equatorward.

A number of other species of birds, including short and long-distance migrants from different countries over the world, have been found to use a magnetic compass; most members of this group are night migrants. Studies in pigeons have suggested that their magnetic compass too, is an inclination compass. This information indicates that the magnetic inclination compass is a very widespread mechanism among birds in general regardless of their relationship, their geographic distribution and their migratory habits. It also indicates that migratory direction is genetically encoded in birds as a compass course relative to the geomagnetic field. In both north and south hemispheres, birds begin their Fall migration heading toward the equator – south for northern birds, north for southern birds.

During homing, the magnetic compass is involved not only in locating the course determined by navigational methods. It seems that it may also be a part of these navigational processes themselves, that is, when these processes are based on information obtained during the trip from the loft to the release point. One experiment showed that young, inexperienced pigeons were disoriented after they were released when they had traveled to the release point in a planned distortion of the magnetic field. However, a second group that had experienced the same distorted magnetic field for the same length of time, this time while they waited at the release site, oriented correctly and headed for home. The authors of this study concluded that it wasn't the distorted magnetic field as such but being transported in a distorted field that was critical. On this basis it has been assumed that pigeons use the magnetic field as a reference system for storing information about the course of the outward trip as well as the homeward course, and that the distortion of the magnetic field during the trip to the release point prevented the first group of birds from storing such information. Only very young inexperienced birds apparently use this strategy; older more experienced birds don't appear to be affected by magnetic distortions during the trip to the release point—which suggests a change in their navigational strategy that may be related to their greater experience.

The magnetic compass is involved in the learning curve that leads to the establishment of the sun compass. Young inexperienced pigeons use the magnetic compass before they can use the sun compass. There is evidence that the magnetic compass serves as a directional reference system to establish the sun compass. Later on, the sun compass becomes the preferred system. When pigeons are used to flying in overcast conditions, their orientation toward home under either sunny or overcast skies is similar, so it would appear that the accuracy of the magnetic compass is equal to that of the sun compass.

How accurate is the magnetic compass? The flight behavior of birds suggests considerable accuracy. When pigeons are released in cloudy conditions in which they have to depend on their magnetic compass, they may produce compass directions of high accuracy, deviating from a direct line by less than 25o.

Research has also shown that there is a pronounced learning stage involving the navigational map during training in the first 2-3 months of life after weaning. There is marked development in the first to second month, followed by a critical period between the second and third months of age, during which development is impaired possibly as a result of a reorganization of the system, and then slight progress occurs in subsequent months. A related study in 2005 concluded that lofts apparently play a central function in the development of the navigational system, but their exact role is unknown.

It is known that a wide group of bacteria and algae orient their movements along lines of the magnetic field. The basis for this ability was determined to be crystals of the magnetic, iron-based minerals magnetite, also known as lodestone (Fe3O4 — ferric oxide), and greigite (Fe3S4 – ferric sulfide). Later, magnetite was also found in honeybees, birds, salmon, sea turtles and a number of other animals known to orient with the magnetic field of the earth.

Most magnetite isolated from animals has been in the form of what are called single-domain crystals that are particles of magnetite that are attracted by a magnet but do not attract iron particles to themselves. In fact, they are extremely tiny permanently magnetized magnets that twist into alignment with the magnetic field. In some animals such as pigeons, magnetite crystals are smaller than single-domain size; these smaller crystals are said to be super para-magnetic and have different magnetic properties. Unlike single-domain crystals, they don't have a permanent magnetic movement and so they can't physically rotate into alignment with the magnetic field of the earth. Even though these crystals don't move, their magnetic alignment tracks the alignment of the surrounding magnetic field.

In order for magnetite crystals to function as magnetic receptors, the assumption is that they must have to make contact with the nervous system. The strongest evidence that this is so is derived from experiments with trout and pigeons. In pigeons and other birds, crystals that are thought to be magnetite have been found in the upper beak. Electron microscopic studies (that magnify many thousands of times) of this area in pigeons have shown that these crystals are located within the ends of nerves and are distributed along the membrane of nerve cells. In pigeons, these crystals have been found to be super para-magnetic. They are present in clusters, and in pigeons about 10-15 of these clusters are found inside the end of one nerve. An interesting similarity between birds and fish is that the location of the crystals in the beak of pigeons and in the nasal area of trout, appears to receive its nerve supply from the ophthalmic (eye) branch of the trigeminal nerve, one of the 10 nerves that originate directly from the under side of the brain. The implication is that the ophthalmic branch of the trigeminal nerve carries to the brain, important information about the magnetic field. (As an aside, these findings indicate that pigeons and other birds readily obtain the extremely tiny amounts of magnetite they need from their regular diet, mineral mix, water, etc., so I have long wondered why fanciers would buy magnetite!)

Adding to the complexity of the problem was the interesting suggestion by some researchers that the magnetic compass of birds might require light for its function. This idea was put to the test by the German research team of Wolfgang and Roswitha Wiltschko who found that European robins that were exposed to the local geomagnetic field oriented correctly in the expected migratory direction under blue, turquoise and green light (short wavelength light) but were disoriented under yellow and red light (long wavelength light). Thus, the orientational responses of birds to magnetic cues seem to depend on the wavelength of light. (When 'white' light from the sun is passed through a prism, it separates in this order into its seven colors — red, orange, yellow, green, blue, indigo and violet—each of which has a different wavelength.

It is interesting that many years earlier, the first attempt by the same authors to establish the role of light in magnetic orientation involved experimental studies with young, inexperienced pigeons. As noted previously, to determine the correct homeward direction, inexperienced young pigeons rely on compass information that they obtain during the trip from the loft to the release point. If these inexperienced pigeons are transported in the normal geomagnetic field and in darkness as well, they become disoriented when they are released. (However, experienced older pigeons aren't affected by similar treatment.) These findings in young pigeons are consistent with their use of a magnetic compass mechanism that also depends on light for correct orientation to the home loft. Experiments with young homing pigeons suggest a similar relationship between the wavelength of light and the ability to obtain directional information from the magnetic field. In summary, the available data indicate that light from the blue-green part of the visual spectrum is required for magnetic reception in birds.

To add to this discovery, the same researchers found that that the effect of light on the magnetic compass in European robins was processed through only one eye: the right one. When a cap was placed over the left eye, these birds continued to orient correctly, but when the right eye was covered, the birds became disoriented. Similarly, work with pigeons showed that birds with the left eye covered homed consistently better than those with the right eye covered. Because the left side of the brain controls the right side of the body - and vice versa - these findings suggested the importance of the right eye and left side of the brain in processes involving flight control, navigation and homing in pigeons.

Adding further to the navigational mix is the controversial subject of odors and their role in the navigation of pigeons. In 1971 an Italian scientist named Papi and his colleagues proposed the idea that odors played an important role in navigation and homing by pigeons. In the years since then the issue has remained contentious and has resulted in many experiments, theories, proponents and of course, dissent.

The basic premise behind this idea is that pigeons learn an odor 'map' by associating odors detected at the home loft with the