28th July 2008

# Nature and the magnetic compass

Blue light and a special protein help birds use the earth's magnetism to find their way, says S.Ananthanarayanan.

That birds and many living organisms use the earth's magnetic field to orient behaviour has been known for decades. But what could be the physical basis for such sensitivity has been elusive. One possibility is that birds have magnetic material embedded in their heads to help the bird sense magnetic force. The other theory is that the body has chemical agents which are sensitive to magnetism. Evidence has been found for both.

**Pigeons follow nose**

The homing pigeon has remarkable sense of direction. Pigeons can remember pathways that do not depend on visual signposts - for instance, getting to their 'home' rooftop even when landmarks are pulled down. They can do it when the sun shines from different directions at different times of the day or when it is overcast and the sun cannot be seen.

Dr Cordula Mora and her team in Aukland, New Zealand found that pigeons actually sense magnetic fields through iron-rich materials found in their beaks. The birds were placed in a cylinder with a food tray at both ends and an electric coil to create a magnetic field. Food was placed at one end of the cylinder, so that the birds were rewarded if they followed the field and moved the correct way. The birds were found to learn very fast, which means they could clearly sense the magnetic field, as if it were a colour or sound of a particular pitch.

But if small magnets were taped to their beaks, or if the beaks were anaesthetized, the birds did not react to changing the direction of the field. This showed that it was in the beak that the birds had their magnetic field sensing equipment.

**Sensitive to light**

There is also evidence that with many birds, the sensors of magnetic fields is located in the eyes and depends on certain shades of light being present. This suggests a different mechanism – one where light of specific energies sets off a chemical process which depends on the orientation of the magnetic field. If this process is perceptible to the bird, it could adjust its direction of flight according to the magnetic field! A paper in ***Nature***, published in July 2008, reports the identification of such a mechanism.

A simple chemical arrangement that is sensitive to magnetic fields is a pair of electrically charged groups of atoms. Molecules are generally formed by atoms or groups of atoms which mutually borrow and lend charged particles, to get both groups into a more stable condition – a kind of co-operative co-existence. But the partners also get separated sometimes, and they float in their 'more stable' state, but with a net charge so long as they are separate. Such free-floating charged segments of groups of atoms are called ***radicals*** and a pair of them would be a ***radical pair***.

Pairs of radicals are then lightweight but important players in chemical reactions and they have strong magnetic properties. Because they are magnetic, a magnetic field could orient them to react in one way when the field is strong and another way when the field is weak. The radicals would then go for one chemical reaction in one kind of magnetic field and for another reaction when the field is different. If the different reactions could affect the light sensitivity of the eye, differences in magnetic fields may be perceived in some visual manner!

**Cryptochrome**

Cryptochrome (**Cry**)is a protein that is found in many plants and animals. The protein appears to become chemically active when exposed to light of specific colours. In plants, this kind of protein regulates, for instance, the tendency of the plant to grow towards the source of light. **Cry**s are seen as important in maintaining the circadian clock – or the cycle of night and day – based on light and dark. And there has been evidence that **Cry**s found in the retina of birds plays a role in their magnetic sensing.

A team of 4 scientists at the University of Massachusetts Medical School, USA report studies on **Cry** of the fruit fly, which show that the protein is necessary for magneto-sensitivity, which appears in the presence of ultra violet or deep blue light.

The scientists devised an apparatus where fruit flies could be selectively exposed to a magnetic field as well as to light passed through specific filters. Flies that responded by choosing a particular one of the two arms of a junction in their path, when the magnetic field was switched on, were rewarded with sucrose.

It was found that the flies were readily trained to select the correct path every time the magnetic field was switched on but this was only when particular shades of blue was there in the light streaming in. The trained response did not appear when light of 420 nanometres (deep blue light) was blocked out by filtersw. This indicates that the particular shade of light is essential for the magnetic response mechanism to work.

Another test was to try it out with fruit flies that had been bred to lack the **Cry** protein. It was found that these modified flies just did not display sensitivity to magnetic fields, regardless of the shades of light used, along with various strengths of the field. This indicates that it is the **Cry** protein, which is switched on by blue light, which is needed to respond to magnetic fields.

**Partners in time**

Another protein called ***Timeless*** has been identified as the one that enables the setting of the circadian, or day-night, clock in many organisms. ***Timeless*** works with Cryptochrome-2, the photoreceptor, and then a protein called ***Period*** in its action of setting the cycle of bio-rhythms. An example is the opening of the leaves of the heliotrope plant in the morning, and closing at dusk, to the cycle of signals of day and night. The action of ***Timeless***, once set, persists even when the time signal is switched off - the heliotrope keeps opening and closing every 12 hours even when it is enclosed in a continuously dark place.

As ***Cry*** interacts with ***Timeless*** in setting the circadian clock, a control check on magneto-sensitivity of the fruit fly was carried out to verify whether a working circadian system was necessary for the **Cry** protein to bring about magneto-sensitivity. For this, the circadian rhythm of fruit flies was first destroyed by exposure to constant light, which degrades not only **Cry** but also **Timeless** and **Period**. Five days of such exposure was seen to break down the regularity of day-night behaviour. When the experiment was done with these a-rhythmic fruit flies, it was found that they were as readily trainable to respond to a magnetic field when the circadian cycle was destroyed as when the cycle was intact.

The Massachusetts group appear to shown clearly that it is ***Cry*** that the one that brings about magneto-sensitivity and it is activated by blue light!