Indian J.L.Sci. 5(1): 135-151, 2015

ISSN: 2277-1743 (Print)
ISSN: 2278-7879 (Online)

REVIEW ARTICLE MAGNETIC FIELD EFFECT ON BIOLOGICAL SYSTEM

NEHA JAIN[a1], MAYA SHEDPURE[b], RICHA TIKARIHA[c], PREETI KARANJGAONKAR[d], MAMTA RATRE[e] AND SWETA AGNIWANSHI[f]

[abcdef]Department of Zoology, Govt. D. B. Girls' P.G. (Auto.) College, Raipur, Chhattisgarh, India

ABSTRACT

The magnetic field is a mathematical means of representing the magnetic force. Electric and magnetic fields arise from many natural sources. They appear throughout nature and in all living things. Animal systems have been examined under a range of electric and magnetic field intensities and for varied exposure conditions and durations. Historically, the animal experiments began by looking for general effects rather than by formulating and testing hypotheses because there was no indication about what system or function, if any, is most likely to be affected by fields. However, now there is a very large number of scientific findings based on experiments with animals and people which suggested that low frequency magnetic fields can interact with, and produce changes in biological system.

KEYWORDS: Biological system, magnetic field, physiology, hematology, reproduction, pineal gland.

Our senses tell us what we need to know about our environment. They help to keep us out of danger and enable us to find food and shelter. As humans, our senses include sight, sound, taste, smell, and touch. But other animals need different information about the world to survive than we do. They may have senses like ecolocation, infrared vision, electric sense, magnetic sense etc [klappenbach, 2009]. Toothed whales, bats, and some shrews use ecolocation to navigate their surroundings. Each of these animals emits high-frequency sound pulses and, in turn, detects the echoes produced by those sounds [klappenbach, 2009]. Rattle snakes and other pit vipers use their eyes to see during the day, but at night they use infrared sensory organs to detect and hunt warm-blooded prey [klappenbach, 2009]. Electric fields are also used in numerous ways by animals. Electric eels and some rays have modified muscle cells that produce an electric charge strong enough to shock and sometimes kill their prey. Other fish use weaker electric fields to navigate murky waters or to monitor their surroundings (Klappenbach, 2009). In addition, all organisms have a biologic sensitivity to the earth's magnetic field [Internet source, 2008].

MAGNETIC SENSITIVITY

The magnetic field is a form of energy to which all plants and animals are exposed. However, its influence on living systems is not well understood (Internet source A, 2009). The flow of molten material in the earth's core and the flow of ions in the atmosphere generate a magnetic field that surrounds the earth (Klappenbach, 2009). All points on the earth's surface are characterized by the presence of a static geomagnetic field (Bochert and Zettler, 2004).

Earth's magnetism is very weak, from 0.3 gauss at the Equator to 0.7 gauss at the Poles. This magnetosphere of the earth affects the life of most creatures on Earth (Anitei, 2008). Since the earth has a magnetic field, any conducting medium moving through it induces an electric field. For an electro sensory animal, two potential mechanisms are available to perceive the magnetic fields: a passive detection of gradients from water currents or an active detection of gradients set up by swimming movements (Wilkens and Hafmann, 2004). Magnetic fields interact directly with magnetically anisotropic or ferromagnetic materials, and with moving charges (Repacholi and Greenbaum, 1999). Static magnetic fields may interact with living systems through magnetic induction (forces on moving ions in solution), magneto-mechanical effects (torques on molecules and ferromagnetic material) and electronic interactions (altering of energy levels and spin orientation of electrons) (Repacholi and Greenbaum, 1999).

Scientists and biologists have long been fascinated by the ability of some fish to use electricity and magnetism to navigate and find prey. It is known that all fish have some reaction to electric stimulus in the water (Internet source B, 2010). Further, the magnetic field is known to exert its influence on both adult and juvenile fishes, as well as the embryos. The effects are diversified and pertain

[1]Corresponding author

to, practically all, life aspects of an individual (Winnicki *et al.,* 2004). It has also learned that many fish have the capability to sense the electrical impulses given off by other fish and some can even sense the tiny voltage gradients created by ocean currents and river water movements in the presence of the earth's magnetic field (Internet source B, 2010). All fish have a reaction to an electrical field but it differs in various groups of fishes. Some fish are attracted to the field, some are frightened by it and attempt to hide and some may appears to be immobilized by it. Interestingly, however, all of these groups react towards the positive charge and away from the negative. Even fish that are frightened and attempt to hide, move in the direction of the positive anode (Internet source B, 2010). Some fish may have special cells on their body surface that are electro receptors. These nerve cells have the specific capability of reading electric signals. Sharks, rays, sturgeon and catfish are some of the better known species of this type. Not only they are attracted by an anode reaction but they use their electro receptors to find prey hidden or buried in the mud or sand. They can sense the electrical nerve discharges of their target (Internet source B, 2010). Studies on trout have linked their response to electrical fields to metabolism. Active fish like trout have a higher rate of metabolism and demonstrate more electrical sensitivity (Internet source B, 2010).

Catfish are long known for their sensitivity to metallic objects (Parker and Heusen, 1917). Depending on the size and kind of metal used, catfish either show avoidance reactions or are attracted and show various feeding behaviors. Since nonmetallic objects are ineffective, it was suggested that catfish respond to the electric fields caused by the electrochemical potential of metals. This was confirmed by using batteries as stimuli, which give better control over the intensity of the electric field (Uzuka, 1934). The responses obtained in that way range from barbel movements, approach and nibbling to avoidance and escape. In general, weaker stimuli resulted in approach and stronger stimuli in avoidance. The high sensitivity in catfish to electric fields was also thought to be a possible explanation for the earthquake predictions by these fish. The unusual behavior of catfish preceding earthquake has been noted on several occasions (Wilkens and Michael, 2004). Catfish are able to detect electric fields with their electroreceptor organs. It goes without saying that the electro detection threshold depends on the sensitivity of the electroreceptor organs. The sensitivity in turn depends on a variety of extrinsic factors such as water temperature, conductivity and electric field frequency (Lonneke et al., 2001).

Behavioral experiments show that elasmobranch fishes (sharks, skates, and rays) can detect changes in the geomagnetic field (Andrianov *et al.,* 1974; Meyer *et al.,* 2005; Murray, 1962), and studies of migration (Klimley, 1993; Bonfil *et al.,* 2005) give strong evidence that several species can navigate over long distances in environments where the geomagnetic field is the only plausible reference (Montgomery and Walker, 2001). Both direct magnetoreception and induction-based electroreception have been proposed as mechanisms for this ability to orient to the geomagnetic field or "compass sense" (Molteno and Kennedy, 2009). All elasmobranch fishes can detect electric fields using small pit organs in their snouts, the ampullae of Lorenzini (Kalmijin, 1966). The ampullae permits detection of both small local electric fields produced by other biological organisms, and large uniform electric fields, such as the earth's magnetic field (Tricas, 2001). This electric sense is known to play a role in many behaviour observed in elasmobranches. It has been suggested that geomagnetic induction of electric current could play a role in orientation behaviour (Kalmijin, 1978, 1982; Paulin, 1995).

Several species of sharks have demonstrated the ability to sense magnetic fields (Kalmijin, 1978; Klimley, 1993, 2002) Whales and dolphins were found to use Earth's electromagnetism in their long migrations (Anitei, 2008). Sharks moving through the terrestrial magnetic field generate an electric field whose value depends on their position of the magnetic field captured by the electroreceptors. In an aquarium, sharks always swim around the walls. If the magnetic field is cancelled or impaired, they start swimming randomly (Anitei, 2008). Fish have a thin line of sensitive cells on their sides which sense movement or vibration in the direction of the current (Internet source, C).

Further, it has been discovered that magnetic bacteria living in the ponds and lakes, those located in the Northern Hemisphere swim in the direction of the magnetic north, while those from the Southern Hemisphere swim in the direction of the magnetic south (Anitei, 2008). Plant seeds do not germinate in cosmos, as they must feel the terrestrial magnetic field so their cells can be activated. When seeds are put in a more powerful magnetic field than that of the earth, a 15 % increase of the production was caused. If bees are subjected to a magnetic field ten times more powerful than the terrestrial one, they are completely disoriented, and the combs get unusual forms and orientations (Anitei, 2008).

Salamanders, frogs use the magnetic field for orientation when they have to find the direction of the nearest shore quickly, Migratory birds use magnetic clues (in addition to light polarization, star signs, position of the sun) to find their way south in fall and north in spring (Internet source D, 2007).

It has been suggested that each of these animals has deposits of magnetite in their nervous systems. Magnetite, small magnet-like crystals, align themselves with magnetic fields and might act like microscopic compass needles. These crystals may be the key to revealing how animals sense magnetic fields (Klappenbach, 2009).

The tiny deposits of a magnetite were discovered in the beaks of pigeons and bobolink. If a small magnet impairs their reception of the earth's magnetism or the area has a natural disturbance of the terrestrial magnetism, pigeons get disoriented and cannot find the way back on long distance (Anitei, 2008).

Birds and many non-mammal magnetic sensitive animals are known to perceive the inclination, using the Earth's magnetic field inclination to assess relative latitude. A bird species, Arctic Tern, use this information to make annual journeys from the North Pole to the South Pole and back (Anitei, 2008).

Marine turtles use to return to the same breeding beach, often located thousands of kilometers off the feeding places, making the return with no visual land marks but relies on detecting the earth's magnetic field, against the deflection induced by the ocean currents (Anitei, 2008). If a powerful magnet attached on the turtles' heads impairs the detection of the earth's magnetism, the turtles decrease their navigational sense (Anitei, 2008).

The magnetic compass, using the terrestrial magnetism, is also used by moles, rats, fish and amphibians. Bats also have the ability to detect the difference between north and south. They use the terrestrial magnetism for long-distance navigation and foraging abilities

Lab mice that had formed the conditional reflex of pressing a flap to get food any time they wanted to eat lost their reflex after being kept for 10 days in a room were the terrestrial magnetism was impaired (Anitei, 2008).

Although the use of the geomagnetic field for directional information is well established experimentally, it is not known by which biophysical mechanism magnetoreception is achieved (Internet source D, 2007).

How does the animal brain process magnetic information Past studies have shown that some species have particular brain areas that respond to magnetic information. These areas may also have nerve cells that detect changes in the magnetic field. And the presence of the naturally magnetic mineral magnetite in the brains of some animals triggers magnetoreception (i.e. the ability to detect a magnetic field, to perceive direction, altitude or location) (Internet source E, 2009).

The effects of various types of magnetic fields on living organisms has been a subject of increasing interest in recent years for both theoretical and practical reasons. "Basically, the magnetic field, being a form of energy, just as are light, heat and sound, impinges upon all living organisms whether plants or animals. The question as to its effect on living matter is what we are seeking to learn. Is it an active or passive process? How will an organism react to an environment that is devoid of a magnetic field? Further, what will happen if the field is altered or distorted (Caldwell and Russo, 1968).

Therefore, in the present study, it was aimed to examine the effect of pulsed and continuous magnetic field exposure on metabolic and physiological activities of catfish, *Clarias batrachus* and *Clarias gariepinus*.

Effect of magnetic field exposure on biological system

Living systems are very, sensitive to magnetic fields and the magnetic effect reaches every cell in the body on account of the highly pervasive character of magnetism. (Internet source F, 2009). Magnetism is a force that acts at a distance and is caused by a magnetic field (Kurtus, 2006). Our body's natural magnetic field is created by the flow of electrically charge ions in and out of cells and the transmission of electric impulses through membranes (Internet source G, 2009). Many biological processes are affected by electromagnetic fields. Magnetic fields interact with biological systems through forces on the electrical currents associated with physiological functions and through the torques exerted on the magnetic moments of biologically important molecules (Adair, 2000). Bioelectrical phenomena, underlying all vital functions of living organisms are determined by metabolism controlling mechanisms. The interactions between external fields (including the terrestrial magnetic field) and internal electromagnetic ones results in release of the so called activation energy of potential substrates, making them ready to enter into reactions. The mechanisms may be regulated by means of specific external electromagnetic fields, thus affecting life functions (Milewski et al., 2001).

When a magnet is applied to the body, magnetic waves pass through the tissues and secondary currents are induced. When these currents clash with magnetic waves, they produce impacting heats on the electrons in the body cell (Bansal, 2006). Earlier reports suggested that magnetic field affects the living body by various ways (Milewski et al., 2001].

The pineal gland in the center of our head controls hormones, enzymes and immune function, and is itself magnetic organ containing magnetic crystals. It is acutely sensitive to magnetic energy and produces it's most important and characteristic substance, the sleep hormone melatonin, almost entirely during the night when the earth's negative field is dominant (Phillpott, 2006). Therefore, there is evidence that the pineal gland is a “Magnetosensor” in the brain, since experimental animals exposure to external magnetic fields alters the firing rate of pineal cells and induces inhibition of melatonin secretion (Sandyk, 1993).

Further, it has been unequivocally accepted that pineal organ acts as a neurochemical transducer of photoperiodic information and linked to several physiologic processes in various vertebrate species including fishes (De vlaming and Olcese, 1981; McNulty, 1984; Burns, 1972; Delahunty et al., 1978; Innocenti et al., 1993; Shedpure and pati, 1995).

During the last 50years, the nature and scope of the magnetic field and its effect on living organisms have been studied. Thousands of experiments on bacteria, flies, mice, birds, fish, pigeons and rabbits as well as on the plants and tissue cultures have been conducted and astonishing facts revealed (Internet source, F, 2010).

PLANTS

In general, earlier studies on plants suggested a beneficial effect of magnetic field exposure on plant growth and production [Internet source H, 2000]. Exposure of magnetic field has been suggested to increased sprouting and growth of seedlings and fast fruit and vegetable ripening Internet source H, 2000.

It has been discovered that plants kept, within the magnetic field grow faster and give far better results in the form of greenery and fruits [Internet source F, 2010].

MICROORGANISMS

Effect of magnet has also been seen on the activity of certain bacteria specially those which are harmful and produce diseases in human beings. One such organism studied by the scientists is *Staphylococcus aureus* which produces skin troubles, stomach disorders and in certain troubles in human beings. These bacteria when incubated in the magnetic fields of 15 kilo-gauss showed complete inhibition of their development after 6 hours. Similarly, *Serratia marcesscens* and *Eschirichia coli* which produce intestinal disorders in human beings and animals, have been shown to exhibit partial or complete inhibition of their growth under magnetic field (Internet source H, 2000).

However, magnetic field exposure of

nutritional medium of microorganism has been found to increase the growth rate, biomass accumulation and biosynthetic activity of microorganisms (Erygin et al., 1988). In addition, decrease in growth rate of unicellular organisms, i.e. paramaecium [Elahee and Poinapen, 2006] and *Fusarium culmorum* (Albertini et al., 2003) have been suggested by exposure under magnetic field.

ANIMAL BEHAVIOUR

It has been suggested that behavioral responses of living organisms are greatly dependent on the ambient magnetic fields (Tenforde, 1979; Blank, 1993; Wiltschko et al., 1995a). An inhomogeneous, static magnetic field has been documented to reduce the flying activity of bees (Martin et al., 1989). Magnetic fields has been found to affect the selection of migration direction and navigation of numerous fish species. Such responses were found in salmonids such as smolts and juveniles of sockeye salmon *Oncorhynchus nerka* (Quinn et al., 1981; Quinn & Brannon, 1982) *Chum Salmon* (*O. keta*) [Yano et al., 1997], *Rainbow trout* (*O. mykiss*) (Walker et al., 1997; Chew et al., 1989) *Atlantic salmon* (*Salmo salar*) (Rommel et al., 1973; Varanelli et al., 1974), *European eel* (*Anguilla*) (Tesch et al., 1992), *American eel* (*Arostrata*) (Rommel et al., 1973; Mc Cleave et al., 1978]) *yellowfin tuna* (*Thunnus albacares*) [Walker, 1984] as well as sharks and rays (Kalmijn, 1982).

It has been documented that the fish are capable of developing conditional responses to magnetic fields [Walker, 1984; Kalmijn, 1978; Formicki et al., 2006]. The artificially generated constant magnetic fields were found to induce significantly stronger orientation responses in fish embryo compared to those elicited by the geomagnetic field alone. (Tanski et al., 2005).

Anadromous rainbow trout has been found to align along an external magnetic field, but become disoriented in a null magnetic field [Chew and Brown, 1989]. It can discriminate between superimposed magnetic field, but only when the conditional response allows movement and when the magnetic fields are spatially distinctive [Walker et al., 1997]. Experiments with yellow fin Tuna (Thunnus albacares) showed that they reacted to differences in intensity of magnetic field but not to differences in direction [Walker, 1984].

In mice, static magnetic field exposure has been shown to reduce the activity of mating behaviour (Zimmerman and Hentschel, 1987). In deer mice, increase of spatial learning by magnetic field exposure has been documented (Kavaliers et al., 2004).

HEMATOLOGY

Magnetic energy has a beneficial effect on blood circulation, lymph flow, hormone production, nerves and muscles (Warnke, 2006). Movement of hemoglobin in blood vessels is accelerated due to presence of ferric ions while calcium and cholesterol deposits in blood are decreased (Bansal, 2006). Even the other unwanted materials adhered to the inner side of blood vessels, which provoke high blood pressure, are decreased and made to vanish. The blood is cleansed and circulation is increased. Most often it is used to bring the blood back to its natural healing polarity. Increase blood flow, bringing in more oxygen and nutrients and flushing away waste products have also been reported by magnetic field exposure (Johnston, 2006).

Magnetic field exposure has been reported to increase the immature and mature erythrocytes in mice (Svedenst and Johanson, 1998). It has been reported that the exposure of rats 1 hour/day for 13 consecutive days to static magnetic field induced an increase in hematocrit level, hemoglobin concentration and LDH levels (Chater et al., 2006). In mice, exposure of extremely low frequency magnetic field has been suggested to cause leucopenia (Carbrales et al., 2001; Picazo et al., 1995a; Picazo et al., 1994; Vallejo et al., 2001). However, contrary reports are available, i.e., red cell number, hemoglobin content and hematocrit have been reported to decrease in mice exposed under extremely low frequency magnetic field (Picazo et al., 1995a; Cabrales et al., 2001).

In rats, electromagnetic field (EMF) exposed water has been suggested to cause leukocytosis and thrombocytosis on 30 days, and leucopenia and thrombopenia on 60 days (Singh *et al.,* 1995). It has been reported that chronic exposure to a 0.2-6.6- μT magnetic field can lead to decreased total lymphocytes in humans and mice (Bonhomme-Faivre et al., 2003).

Bonhomme- faivre and his coworkers, 1995 have also reported decline in number of leukocytes, lymphocytes, monocytes and eosinophils in mice depending on the duration of exposure to magnetic field. In contrast, in human, exposure under electromagnetic field has been reported to cause an increase in the white blood cells (Marino, 1995).

An earlier reporte on guinea pig suggested a decrease in platelet count and an increase in platelet aggregation after exposure under magnetic field [Gorczynska and Wegrzynowicz, 1983]. Results (Jain, 2010) emerged from our laboratory suggested that pulsed magnetic field exposure may cause beneficial effect on hemopoietic variables and may be advantageous for body weight gain in *C. batrachus,* irrespective of photoperiod and phase of the annual reproductive cycle.

PHYSIOLOGICAL AND BIOCHEMICAL ACTIVITIES

Artificial magnetic fields have been reported to influence some physiological processes in bees. (Martin et al., 1989). Magnetic field has been reported to alter the acidity or alkanity of body fluids and cell chromosome alignment, enzyme activity and other biochemical processes, such as the production of ATP molecule (Johnston, 2006).

Static magnetic field exposure has been reported to cause significant disruption in the carbohydrate, lipid and protein metabolism reflected by altered blood glucose levels and accelerated glycolysis and glycogenolysis in rats (Day, 1999; Salem *et al*, 2005; Picazo I 1995a; Sert *et al.,* 2000; Al-Akhras *et al.,* 2001). An increased blood glucose and decreased insulin release, by exposure to static magnetic field in rats (Chater *et al.,* 2006).

Milewski *et al.,* [2001] have studied that pulsed electromagnetic field stimulation may cause increase in intensity of lipid metabolism in sheep. Pulsed electromagnetic exposure has been reported to alter the dynamics of intracellular calcium in astrocytoma cells in human (Pessina *et al.,* 2001). Basal calcium ion level and levels of interleukin-6 in astrocytoma cell increased after exposure under pulsed magnetic field exposure in human (Aldinucci *et al.,* 2000). Movement of calcium ion increased in lymphocytes in human after receiving electromagnetic field (Aldinucci *et al.,* 2003). An increase of Na and K content in urine in mice by exposure under magnetic field has also

Exposure of mice under static magnetic field has been reported to cause an increase in endochondral ossification on chondrocytes (Okazaki *et al.,* 2001). Frequency of magnet dependent effect of magnetic field was documented on degeneration of cancer cells in mice (Internet source H, 2000).

Varying reports on the effect of magnetic field exposure on sciatic nerve regeneration are also available. An increase in sciatic nerve regeneration was documented by pulsed magnetic field exposure in rats (Kanje *et al.,* 1993; Rusovan *et al.,* 1992). However, no effect on sciatic nerve regeneration by pulsed magnetic field exposure in rat has also been documented by Guven *et al.,* [2005]. An intensity of magnet independent effect of magnetic field exposure on thrombolytic process has been documented in rabbit. An increase in liquefaction of clot by constant magnetic field in rabbit has been reported (Gorczynska, 1986). Magnetic field exposure has been found to produce time of exposure dependent effect on body weight in mice (Svedenstal and Johanson, 1995; Forlen *et al.,* 1993). Body weight loss was reported after postnatal exposure to static magnetic field of mice (Barnothy, 1964; Nagakawa, 1979). However, no significant differences in body weight gain of mice and rat were reported by electromagnetic field exposure (Bellosi *et al.,* 1984). An earlier work conducted in our laboratory suggested that Continuous magnetic field exposure may be helpful in increasing the content of protein in muscle in *Clarias batrachus* (Jain, 2010).

IMMUNE SYSTEM AND AGING

Exposure to power-frequency fields produced changes in the immune system (Malagoli *et al.,* 2003). The normal life span has been reported to increase by exposure under the magnetic field in mice (Internet source I, 2009) and bees (Martin, 1989). Several scientists (Internet source I, 2009) have carried out experiments with different poles of magnets and have come out with a positive assertion that cancer cannot exist in a magnetic field. With the application of the north pole of the magnet, it was found that the cancerous tumours gradually shrank in size and ultimately disappeared totally. But the exact opposite effect was noticed when the south pole was applied (Internet source I, 2009), the tumours increased rapidly and killed the mice. The life of the houseflies doubled by prolonged feeding of magnetized sugar (Internet source I, 2009).

DEVELOPMENT AND REPRODUCTION

Pulsed low frequency electromagnetic field exposure has been reported to accelerate the development of sea urchin (Falugi *et al.,* 1987). However, another report (Zimmerman *et al.,* 1990) on sea urchin has suggested delayed development by exposure under extremely low frequency electromagnetic field. Cleavage plane has been found to altered in frog by exposure under strong static magnetic field (Denegre *et al.,* 1998). In rainbow trout, enhancement of fertilization has been reported by exposure under magnetic field (Strand *et al.*, 2005). Similarly, in sea trout magnetic field exposure has been reported to increase the percentage of egg fertilization (Formicki *et al.,* 1991).

Extremely low frequency magnetic field has been found to produce varying effect i.e. no effect (Maffeo *et al.,* 1984), inhibitory effect (Delgado et al., 1982), and time of exposure dependent effect [Ubeda *et al.,* 1983] on chick embryogenesis. Early hatching in fertile hen's egg has been documented by short period exposure to magnetic field (Internet source H, 2000).

No change in testiculer weight in mouse (Tablado *et al.,* 1996) and rat (Chapin *et al.,* 1984) by magnetic field exposure has been reported. However, extremely low frequency electromagnetic field exposure has been reported to cause an increase in testicular weight in rat (Ossenkopp *et al.,* 1972). Further, no effect of magnetic field on reproduction and embryo fetal development has been documented in rat (Negichi *et al.,* 2002) and mice (Ohnishi *et al.,* 2002). Exposure under high static magnetic field has been reported to decline the mating in mice (Zimmermann and Hentschel, 1987).

The exposure time dependent effect of magnetically pregenerated water was noticed on oestrous cycles and body weight changes in cycling female albino mice (Pandey *et al.,* 1996).

ENDOCRINE SYSTEM

Magnetic field have been found to promote the secretion of different hormones (Johnston, 2006). It has been suggested that electromagnetic field is able to change the serum levels of ACTH, cortisol and glucose (Zare *et al.,* 2005). A time of exposure dependent effect of magnetic field has been suggested on the level of cortisol in guinea pigs by Zare and his coworkers [Zare *et al.,* 2005]. An increase in the level of ACTH has also been reported in guinea pig by exposure under magnetic field (Zare *et al.,* 2005; Lymangrover *et al.,* 1986).

The magnet has been reported to cause effect on the adrenal gland and its hormone aldosterone (Internet source H, 2000). Coincident nonlinear changes in the endocrine and immune systems due to low-frequency magnetic fields have been observed in mice (Andrew, 2001) been reported (Internet source H, 2000). Further, in mouse decrease of Ca ion concentration in skeletal muscle has been reported by magnetic field exposure (Picazo et al., 1995b).

PINEAL ACTIVITY

The pineal gland and its main hormone, melatonin, have been widely reported sensitive to electromagnetic field exposure (Reiter, 1994; Yellon, 1994; Rosen *et al.,* 1998; Lerchl *et al.,* 1998; Karasek *et al.,* 1998; Reiter *et al.,* 1998). Exposure to low frequency electromagnetic field may supress the synthesis of the idoleamine hormone melatonin in the pineal gland of some species (Reiter, 1993; Kato *et al.,* 1994; Yellon, 1994).

In a teleost fish, brook trout (*Salvelinus fontinalis*) significant increase in night-time pineal and serum melatonin level was noticed after exposure under magnetic field (Lerchl *et al.,* 1998). Magnetic field has been shown to affect hormone production of pineal gland, which initiates a cascade of biological effects (Johnston, 2006). In mammalian species magnetic field exposure has been reported to decrease the melatonin secretion from pineal gland and the night time peak of melatonin (Touitou *et al.,* 2002; Repacholi and Greenebaum, 1999; Kato *et al.,* 1991; Bonhomme-Faiver *et al.,* 1998; Wilson *et al.,* 1999). An alteration in normal circadian rhythm of melatonin synthesis has also been reported in animals and humans by (Wilson *et al.,* 1989). However, in human no effect has been suggested on the level of melatonin (Touitou *et al.,* 2002).

Further, it has been suggested that the effect of electromagnetic field exposure on pineal function is similar to that of light which is the main environmental cue mediating the response to photoperiod in mammals and birds (Reiter, 1980).

LIGHT DEPENDENT MAGNETORECEPTION

In terrestrial organisms, magnetic orientation appears to be mediated by more than one type of mechanisms (for reviews, see Wiltschko and Wiltschko, 1995a; Phillips and Deutschlander, 1997; Deutschlander *et al.,* 1999a; Lohmann and Johnsen, 2000). In some cases, the underlying magnetoreception mechanism appears to be independent of light, e.g. in the subterranean mole rat (*Cryptomys sp.*) (Burda *et al.,* 1990; Marhold and Wiltschko, 1997). In contrast, magnetic compass orientation has been shown to be sensitive to the wavelength and/or intensity of light in the eastern red–spotted newt (*Notophthalmus viridescens*) (Phillips and Borland, 1992a; Deutschlander *et al.,* 1999a; Deutschlander *et al.,* 1999b), bullfrog (Rana catesbeiana; M. J. Freake, S. C. Borland and J.B. Phillips, manuscript in preparation and unpublished data), fruit fly (*Drosophila melanogaster*) (Phillips and Sayeed, 1993), homing pigeon (*Columba livia*) (Wiltschko and Wiltschko, 1998) and several species of migratory bird (Wiltschko *et al.,* 1993; Wiltschko *et al.,* 2000a; Wiltschko *et al.,* 2000b; Wiltschko and Wiltschko, 1995b; Wiltschko and Wiltschko, 1999; Rappl *et al.,* 2000). Pineal complex of lizards and anuran amphibians exhibit spectral properties that are consistent with the behavioral responses in the newt (Eldred and Nolte, 1978; Solessio and Engbretson, 1993).

The role of the pineal gland as a neuroendocrine transducer in mammals is now well established. It exhibits circadian rhythmic activities, responds to photoperiodic stimuli, and transmits these stimuli to modulate the functional status of many other endocrine glands (Quay, 1974; Wurtman, 1980; Reiter, 1980; Banerji *et al.,* 1980). The pineal gland is also known to have an anti-gonadal effect in mammals. The existence of pineal's anti-gonadal effects in some sub-mammalian species, especially those characterized by a defined annual reproductive cycle, has also been reported (Maitra and Dey, 1994a, 1994, 1996).

While the pineal is a discrete endocrine gland present dorsally in the epithalamic area of the brain in mammals, in lower vertebrates the pineal organ has been reported to show a wide range of structural variabilities (Van de Kamer, 1965; Vollrath, 1979). From an evolutionary perspective, it becomes readily apparent that the structure and function of the pineal gland have undergone a clear transformation from being primarily a sensory organ in lower vertebrates to an important endocrine gland in mammals. It is noteworthy that the pineal organ in some lower vertebrates exhibits both sensory as well as secretory functions (Falcon *et al.,* 1992; Gern *et al.,* 1992; Okimoto and Stetson, 1999). Evidence has also been presented that the pineal organ in some lower vertebrates is directly photosensitive (Ekstrom and Meissl, 1997). The teleostean pineal organ has been suggested to serve as an important component of the photo-neuroendocrine system transmitting and transducing photic signals into neuroendocrine messages (De Vlaming and Olcese, 1981; McNulty, 1981, 1984; Korf *et al.,* 1998).

The effect of light on magnetic orientation responses (e.g. shifts in the direction of orientation or disorientation) and the wavelength dependence of these effects vary considerably among newts, bees and birds. In addition, several animals are able to orient using magnetic cues in the absence of light (Arendse, 1978; Lohmann, 1991; Lohmann and Lohmann, 1993; Marhold and Wiltschko, 1997) and numerous experiments have provided evidence for a non-light dependent mechanism of magnetoreception involving permanently magnetic material, possibly biogenic magnetite (Kirschvink *et al.,* 1993; Wiltschko *et al.,* 1994; Beason *et al.,* 1995; Walker *et al.,* 1997).

Further, application of a magnetic field has the virtues of simplicity, freedom from danger and low cost. Electromagnetism and its effects on the body may be one of the most exciting scientific breakthroughs in current research and needs to be worked out thoroughly.

ACKNOWLEDGEMENT

Authors are thankful to Chhattisgarh council of Science and Technology, Raipur for financial

support.

REFERENCES

Adair RK, 2000. Static and low-frequency magnetic field effects: health and therapies. Rep. Prog. Phys. 63: 415-454. Al Akhras MA, Elbetieha A, Hasan MK, Al-Omari L, Darmani H and Albiss B. 2001. Effects of extremely low frequency magnetic field on fertility of adult male and female rats. Bioelectromagnetics 22: 340-344.

Albertini MC, Accorsi A, Citterio B, Burattini S and Piatti E, 2003 . Morphological and biochemical modifications induced by a static magnetic field on *Fusarium culmorum.* Biochimie. 10: 963-70.

Aldinucci C, Garcia JB, Palmi M, Sgaragli G, Benocci A, Meini A, Pessina F and Rossi G P, 2003. The effect of exposure to high flux density static and pulsed magnetic field lymphocyte function. Bioelectromagnetic 24 (6): 373-9.

Aldinucci C, Palmi M, Sgaragli G, Benocci A, Meini A, Pessina F and Pessina G P. 2000. The effect of pulsed electromagnetic fields on the physiologic behaviour of a human astrocytoma cell line. Biochim. Biophys. Acta. 11, 1499 (1-2): 101-108.

Andrew A, Marino Michael R, Wolcott and Robert. 2001. Coincident nonlinear changes in the endocrine and immune systems due to low-frequency magnetic fields. Neuro Immuno Modulation 9: 65-77.

Andrianov GN, Brown HR and Ilyinsky OB. 1974. Responses of central neurons to electrical and magnetic stimuli of the ampullae of lorenzini in the Black sea skate. Journal of Comparative Physiology A. 93 (4): pp. 287–299.

Anitei S. 2008. Animal and the magnetic field of the earth. Softpedia 20:36 GMT.

Arendse MC. 1978. Magnetic field detection is distinct from light detection in the invertebrates Tenebrio and Talitrus. Nature 274: 358-362.

Banerji TK, Kachi T and Quay WB. 1980. Adrenal and hypothalamic dopamine-β hydroxylase activity in the hamster: evidence for species distinctive day-night and post-pinealectomy differences in activity. J. Neurosci. Res. 5: 371-378.

Bansal HL. 2006. Magnetic therapy. [Internet sources]

Barnothy JM. 1964. Development of young mice. In: Biological effects of magnetic fields (Barnothy JM, ed). New York: Plenum Press, 93-96.

Beason RC, Dussourd N and Deutschlander ME. 1995. Behavioral evidence for the use of magnetic material in magnetoreception by a migratory bird. Journal Experimental Biology 198: 141-146.

Bellosi A, Sutter-Dub MTH and Sutter BCHJ. 1984. Effect of constant magnetic fields on rats and mice: a study of weight; Aviat. Space Environ. Med. 55: 725-730.

Blankd M. 1993. Electricity and magnetism in biology and medicine. San Francisco press, San Francisco.

Bochert R and Zettler ML. 2004. Long-term exposure of several marine benthic animals to static magnetic fields. Bioelectromagnetics 25: 498-502.

Bonfil R, Meier M and Scholl MC et al. 2005. Transoceanic migration, spatial dynamics, and population linkages of white sharks. Science 310 (5745): pp. 100–103.

Bonhomme-Faiver L, Mace A, Bezie Y, Marino S, Bindoula G, Szekely Frenois N, Auclair H, Arbouys OS and Bizi E. 1998. Alterations of biological parameters in mice chronically exposed to low-frequency (50 Hz) electromagnetic fields. Life Science 62 (14): 1271-1280.

Bonhomme-Faivre L. 2003. Effect of electromagnetic fields on the immune systems of occupationally exposed humans and mice. An International Journal of Archives of Environmental Health 58: pp. 712-717.

Bonhomme-Faivre L, Bizi E, Marion S, Bezie Y, Rudant E, Auclair H and Orbach-Arbouys S. 1995. Effect of subchronic 50-Hz 5-μT magnetic field exposure on hematological parameters in mice. Electromagnetic Biology and Medicine 14: pp. 193-197.

Burda H, Marhold S, Westenberger T, Wiltschko R and Wiltschko W. 1990. Magnetic compass orientation in the subterranean rodent *Cryptomys hottentotus*. Experientia 46: 528- 530.

Burns JK. 1972. Effect of melatonin on some blood constituents and on uterine contractility in the rat. J. Physiol. 226:106.

Cabrales LB, Ciria HC, Bruzon RP, Quevedo MS, Cespedes MC and Salas MF. 2001. ELF magnetic field effects on some hematological and biochemical parameters of peripheral blood in mice. Electromagnetic Biology and Medicine 20: pp. 185-191.

Caldwell WE and Russo F. 1968. An exploratory study of the effects of an magnetic field upon the behavior of the Italian honeybee. J. Genet. Psychol. 113: 233-252.

Chapin RE, Dutton SL, Ross MD, Sumrell BM and Lamb JC. 1984. Development of reproductive tract lesions in male F344 rats after treatment with dimethylmethylphosphanate. Exp. Mol.Pathol. 41: 126-140.

Chater S, Abdelmelek H, Pequignot J M, Sakly M and Rhouma KB. 2006. Effect of sub acute exposure to static magnetic field on hematologic and biochemical parameters in pregnant rats. Electromagnetic Biology and Medicine 25: pp. 135-144.

Chew GL and Brown GE. 1989. Orientation of rainbow trout (*Salmo gairdneri*) in normal and null magnetic fields. Can. J. Zool. 67 (3): pp. 641-643.

Day N. 1999. Exposure to power-frequency magnetic fields and risk of childhood cancer. Lancet, 354: 1925-1931.

De Vlaming VL and Olcese J. 1981. The pineal and reproduction in fish amphibians and reptiles; In: Riter RJ, ed. The Pineal Gland II: Reproductive Effects. Boca Raton, Florida: CRC Press Inc., 1-29.

Delahunty G, Bauer G, Prack M and De Vlaming VL. 1978. Effects of pinealectomy and melatonin treatment on liver and plasma metabolites in the goldfish, *Carrasius auratus*. Gen. Comparat. Endocrinol. 35: 99-199.

Delgado JM, Leal J, Monteagudo JL, and Gracia MG. 1982. Embryological hangesinduced by weak, extremely low frequency electromagnetic fields. J. Anta. 134 (Pt3): 53351.

Denegre JM, Valles JM, Lin K, Jordan WB and Mowry KL. 1998. Cleavage planes in frog eggs are altered by strong magnetic fields. Proc. Natl. Acad. Sci. USA 95 (25): 1472932.

Deutschlander ME, Borland SC and Phillips JB. 1999b. Extraocular magnetic compass in newts. Nature 400: 324–325. Deutschlander ME, Phillips JB and Borland SC. 1999a. The case for light-dependent magnetic orientation in animals. J.Exp. Biol. 202: 891–908.

Ekstrom P and Meissl H. 1997. The pineal organ of teleost fishes. Rev. Fish. Biol. Fisheries 7: 199-284.

Elahee KB and Poinapen D. 2006. Effect of static magnetic fields on growth of paramecium caudatum. Bioelectromagnetics. 27(1):26-34.

Eldred WD and Nolte J. 1978. Pineal photoreceptors: Evidence for a vertebrate visual pigment with two physiologically active states. Vision Res. 18: 29–32.

Erygin GD, Pchelkina VV, Kulikova AK, Rusinova NG and Bezborodov AM. 1988. Influence of the nutritional medium treatment of microorganisms by a magnetic field on growth and development. Prikladnaya Biokhimiya i Mikrobiologiya 24 (2): 257-63 CODEN: PBMIAK; ISSN: 0555-1099.

Russian.

Falcon J, Thibault C and Begay V. 1992. Regulation of the rhythmic melatonin secretion by fish pineal photoreceptor cells; In:Ali MA, ed. Rhythms in Fishes. New York: Plenum Press, 167-198.

Flaugi C, Grattarola M and Prestipino G. 1987. Effects of low-intensity pulsed electromagnetic fields on the early development of sea urchins. Biophys. J. 51 (6): 999-1003.

Formicki K, Sobocinski A, Winnicki A and Mongialo Z. 1991. Effect of fertilization sea trout (*Salmo trutta L.*) eggs with spermatozoa exposed to a magnetic field. Acta Ichthyologica et Piscatoria 21: 99-104.

Formicki K, Tanski A and Winnicki A. 2006. Effect of magnetic field on the direction of fish movement under natural conditions. www.ursi.org/proceedings/ ProcGA02 /Papers/ P0842. Pdf.

Frolen H, Svedenstal BM and Paulsson LE. 1993. Effect of pulsed magnetic fields on the developing mouse embryo. Bioelectromagnetics 14 (4): 393.

Gern WA, Greenhouse SS, Nervina JM and Gasser PJ. 1992. The rainbow trout pineal organ: an endocrine photometer. In: Ali MA, ed. Rhythm in Fishes. New York: Plenum Press, 199-218.

Gorczynska E. 1986. Dynamics of the thrombolytic process under conditions of a constant magnetic field. Clin. Phys. Physiol. Meas. 7: 225-235.

Gorczynska E and Wegrzynowicz R. 1983. The effect of magnetic fields on platelets, blood coagulation and fibrinolysis in guinea pigs. Physiol Chem Phys Med NMR. 1983;15(6):459-68.

Guven M, Gunay I, Ozgunen K and Zorludemir S. 2005. Effect of pulsed magnetic field on regenerating rat sciatic nerve: an in-vitro electrophysiologic study. Int. J. Neurosci. 115 (6): 881-92.

Innocenti A, Minutini L and Foa A. 1993. The Pineal and circadian rhythms of temperature selection and locomotion in lizards; Physiol. and Behav, 53:911. Internet L, Kato, M. and Shigemitsu, T. ELF magnetic field exposure and neuroendocrine response.

Internet source. 2008. Magnetic sensitivity; Urantia News – Verifying history and science in the Urantia book pp. 1-18. Internet source A. 2009 The sensitivity and response of weakly electric fish to static and pulsed magnetic fields. pp. 1-

Internet source B. 2010. Black box techniques; Pro-troll products, 5700A Imhoff Drive, Concord, CA 94520. Internet source C. 2009 Animals have more sense. The Bihar Times.

Internet source D. 2007. The magnetic sense of animals.

Internet source E. 2009. Magnetoreception:. European F. Research Headlines.

Internet source 2010 The story of magneto therapy Indian Gyan.Home. Internet sources G. 2009 Curatronic: Pulsing electromagnetic field therapy.

Internet sources H. 2000. Physical and biological effect of magnets. Indian Gyan.com.

Internet sources I. 2009. Effect on magnetism on animal life in magnetic therapy; Indianet Zone.com.

Jain N. 2010. Magnetic field effect on metabolic and physiological activities of catfish, *Clarias batrachus*. Ph. D. Thesis, Pt. Ravishankar Shukla University, Raipur, India.

Johnston L. 2006. Magnetic healing; what’s the attraction? (Internet sources)

Kalmijn AJ. 1966. Electro-perception in sharks and rays; Nature 212: 1232-1233.

Kalmijn AJ. 1978. Experimental evidence of geomagnetism orientation in elasmobranch fishes, in Animal migration and Homing, Schmidt-Koenig, K. and Keeton, W.T., Eds; Springer Verlag Berlin, pp. 347-353, Kalmijn AJ. 1982. Electric and magnetic field detection in elasmobranch fishes. Science 218: 916-918.

Kanje M, Rusovan A, Sisken B and Lundborg G. 1993. Pretreatment of rats with pulsed electromagnetic fields enhances regeneration of the sciatic nerve. Bioelectromagnetics 14 (4): 353-9.

Karasek M, Woldanska-Okonska M, Czernicki J, Zylinska K and Swietoslawski J. 1998. Chronic exposure to 2.9 mT, 40 Hz magnetic field reduces melatonin concentrations in humans. J. Pineal Res. 25: 240-244.

Kato M, Homna KI, Shigemitsu T and Shiga Y. 1991. Effects of exposure to a circularly polarized, 50 Hz magnetic fields on melatonin levels in rats. Bioelectromagnetics 14: 97-106.

Kato M, Honma K, Shigemitsu T and Shiga Y. 1994. Circularly polarized, sinusoidal, 50 Hz magnetic field exposure does not influence plasma testosterone levels of rats Bio electromagnetics. 15: 513-518.

Kavaliers M, Ossenkopp KP, Prato FS, Innes DGL, Galea LAM, Kinsella DM and Perrot-Sinal TS. 2004. Spatial learning in deer mice: sex differences and the effects of endogenous opioids and 60 Hz magnetic fields. J. Comp. Physiol. 179: pp. 715-724.

Kirschvink JL, Ricci RD, Nesson MH and Kirschvink SJ. 1993. Magnetite-based magnetoreceptors in animals: Structural, behavioral and biophysical studies; Palo Alto, CA: Electric Power Research Institution (EPRI).

Klappenbach L. 2009. The wild side of animal senses; About .com (Internet source).

Klimley AP. 1993. Highly directional swimming by scalloped hammerhead sharks, *Sphyrna lewini*, and subsurface irradiance, temperature, bathymetry, and geomagnetic field. Marine Biology 117 (1): pp. 1–22.

Klimley AP. 1993. Highly directional swimming by scalloped hammerhead sharks, Sphyrna lewini, and subsurface irradiance, temperature, bathymetry, and geomagnetic field. Marine Biology 117 (1): pp. 1–22.

Klimley APSC, Beavers TH, Curtis and Jorgensen SJ. 2002. Movements and swimming behavior of three species of sharks in La Jolla Canyon, California. Environmental Biology of fishes 63: 117-135.

Korf HW, Schomerus C and Stehle JH. 1998. The pineal organ, its hormone melatonin, and the photoneuroendocrine system. Adv. Embryo Cell Biol. 146: 1-100.

Kurtus R. 2006. Magnetism- Succeed in physical science: Rolling friction "School for champions. <http://www school for champions. com/science/frictionrolling htm.

Lerchl A, Zachmann A, Ali MA and Reiter RJ. 1998. The effects of pulsing magnetic fields on pineal melatonin synthesis in a teleost fish; Brook Trout, *Salvelinus fontinalis*); Neurosci. Lett. 13, 256 (3): 171-173.

Lohmann KJ. 1991. Magnetic orientation by hatching loggerhead sea turtles (Caretta caretta). *Journal Experimental Biology.* 155: 37-49.

Lohmann KJ and Johnsen S. 2000. The neurobiology of magnetoreception in vertebrate animals. Trends Neurosci. 23: 153–159.

Lohmann KJ and Lohmann CMF. 1993. A light independent magnetic compass in the leatherback sea turtle. Biol. Bull. 185: 149-151.

Lonneke BME, Robert CP, Franklin B and Wim JGL. 2001. Electroreception of catfish *Ictalurus nebulosus* in uniform and non uniform DC fields: detection threshold and body length. Belg. J. Zool. (Supplement 2): 73-78.

Lymangrove JR, Keku E, Hsieh ST, William P, Dunlap and Seto YJ. 1986. Direct power-frequency electric field effects on mammalian endocrine tissue. Envir. Res. 43: 157.

Maffeo S, Miller MW and Carstensen EL. 1984. Lack of effect of weak low frequency electromagnetic fields on chick embryogenesis. J. Anta. 139 (Pt4): 613-8.

Maitra SK and Dey M 1994 Cytological variation in the pineal organ of roseringed parakeets (*Psittaculka krameri*) with respect to artificial photoperiods and annual cyclicity in testicular functions. Bio. Rhythm Res. 25: 76-88.

Maitra SK and Dey M. 1994a. Castration and testosterone induced changes in the pinealocytes of roseringed parakeet, *Psittacula krameri*, during different phases of the annual testicular cycle. Anat Anzeiger 176: 363-368.

Maitra SK and Dey M. 1996. Cytology of the pineal organ with respect to testicular function in roseringed parakeet (*Psittacula krameri).* In: Haldar C, ed. Recent Researches in Biology: The pineal Gland: Its molecular Signals. New Delhi, India: Hindustan Publishing House, 45-59.

Malagoli D, Gobba F and Ottaviani E. 2003. Effect of 50-Hz magnetic fields on the signalling pathways of FMLP-induced shape changes in invertebrate immunocytes: the activation of an alternative stress pathways. Biochimica. et Biophysica. Acta (BBA)-General Subjects, 1620: pp. 185-190.

Marhold S and Wiltschko W. 1997. A magnetic polarity compass for direction finding in a subterranean mammal. Naturwissenschaften 84: 421-423.

Marino AA. 1995. Time-dependent hematological changes in workers exposed to electromagnetic fields. Am Ind Hyg Assoc J. 56(2):189-92.

Martin H, Korall H and Forster B. 1989. Magnetic field effects on activity and ageing in honeybees. J. J. Comp. Physiol. A 164: 423-431.

Mc Cleave JD and Power JH. 1978. Influence of weak electric and magnetic fields on turning behaviour in elvers of the American eel *Anguilla rostrata*. Mar. Biol. 46: pp. 29-34.

McNulty JA. 1981. A quantitative morphological study of the pineal organ in the goldfish, Carassius auratus. Can. J. Zool. 59: 1312-1325.

McNulty JA. 1984. Functional morphology of the pineal complex in cyclostomes, elasmobranches and bony fishes; In: Reiter RJ, ed. Pineal Research Review 2, New York: Alan R Liss. Inc., 1-40.

Meyer CG, Holland KN and Papastamatiou YP. 2005. Sharks can detect changes in the geomagnetic field. Journal of the Royal Society Interface. 2 (2): pp. 129-130.

Milewski S, Szczepanski W and Depta A. 2001. Level of hematologic and bio-chemical blood indexes in sheep stimulated with BEMER 3000 VET. Mat. Konf. Nauk. Scientific conference materials on the influence of electromagnetic fields on agricultural environment. Lubin, 26-28 Wrzesnia, 151-153.

Molteno TCA and Kennedy WL. 2009. Navigation by induction based magnetoreception in elasmobranch fishes. Journal of Biophysics, Article ID 380976, pp. 6.

Montgomery JC and Walker MM. 2001. Orientation and navigation in elasmobranchs: which way forward?. Environmental Biology of Fishes 60 (1–3): pp. 109–112

Murray RW. 1962. The response of the ampullae of lorenzini of elasmobranchs to electrical stimulation. Journal of Experimental Biology 39: pp. 119–128.

Nagakawa M. 1979. Effect of magnetic fields on fertility general reproductive performance and growth of mice. Jpn. J. Hyg. 34: 488-495.

Negishi T, Imai S, Itabashi M, Nishimure I and Sasano T. 2002. Studies of 50 Hz circularly polarized magnetic fields of up to 350 microT on reproduction and embryo fetal development in rats: exposure during organogenesis or during preimplantation. Bioelectromagnetics 23 (5): 369-389.

Ohnishi Y, Mizuno F, Sato T, Yasui M, Kikuchi T and Ogawa M. 2002. Effect of power frequency alternating magnetic fields on reproduction and pre-natal development of mice. J. Toxicol. Sci. 27 (3): 131-8.

Okazaki R, Ootsuyama A, Uchida S and Norimura T. 2001. Effect of a 4.7T static magnetic field on fetal development in ICR mice. J. Radiat. Res. (Tokyo) 42 (3): 273-83.

Okimoto DK and Stetson MH. 1999. Presence of an intrapineal oscillator in the teleostean family Poecilidae. Gen. Comp. Endocrinol. 114: 304-312.

Ossenkopp KP, Koltek WT and Persinger MA. 1972. Prenatal exposure to an extremely low frequency-low intensity rotating magnetic field and increase in thyroid and testicle weight in rats. Dev. Psychobiol. 5: 275-285.

Pandey S, Garg TK, Singh KP and Rai S. 1996. Effect of magnetically induced water structure on the oestrous cycles of albino female mice *Musmusculus*. Electromagnetic Biology and Medicine 15: pp. 133-140.

Parker GH and Heusen AP. 1917. The responses of the catfish, *Amiurus nebulosus,* to metallic and non-metallic rods. Am. J. Physiol. 44: 405–420.

Paulin MG. 1995. Electroreception and the compass sense of sharks. Journal of Theoretical Biology 174: 325-339.

Phillips JB and Borland SC. 1992a. Behavioral evidence for the use of a light-dependent magnetoreception mechanism by a vertebrate. Nature 359: 142–144.

Phillips JB and Deutschlander ME. 1997. Magnetoreception in terrestrial vertebrates: Implications for possible mechanisms of EMF interactions with biological systems. In The Melatonin Hypothesis: Electric Power and the Risk of Breast Cancer (ed. R. G. Stevens, B. W. Wilson and L. E. Andrews); pp. 111–172. Columbus, OH: Battelle Press.

Phillips JB and Sayeed O. 1993. Wavelength-dependent effects of light on magnetic compass orientation in *Drosophila melanogaster*. J. Comp. Physiol. A 172: 303–308.

Philpott WH. 2006.Biomagnetic hand book.

Picazo ML Vallejo D and Bardasano JL. 1994. An introduction to the study of ELF magnetic field effects on white blood cells in mice. Electromagnetic Biology and Medicine 13: pp. 77-84.

Picazo ML, De Miguel MP and MJ. 1995b. Interactions of EMF magnetic fields with mouse skeletal muscle. Electromagnetic Biology and Medicine 14: pp. 165-175.

Picazo ML, Sanz P, Vallejo D, Alvarez-Ude JA and Bardasano JL. 1995a. Effect of ELF magnetic fields on hematological parameters: An experimental model. Electromagnetic Biology and Medicine 14: pp. 75-89.

Quay WB. 1974. Pineal chemistry in cellular and physiological mechanisms. Springfield, Illinois: Charles Thomas Publishers.

Quinn TP and Brannon EL. 1982. The use of celestial and magnetic cues by orienting sockeye salmon smolts. J. Comp. Physiol. 147A: pp. 137-142.

Quinn TP, Merrill RT and Barnnon EL. 1981. Magnetic field detection in sockeye salmon. J. Exp. Zool. 217: pp. 137-142.

Rappl R, Wiltschko R, Weindler P, Berthold P and Wiltschko W. 2000. Orientation of garden warblers, *Sylvia borin*, under monochromatic light of various wavelengths; Auk 117: 256–260.

Reiter RJ. 1980. The pineal and its hormones in the control of reproduction in mammals; Endocrinol. Rev. 1: 109-131. Reiter RJ. 1993. Static and extremely low frequency electromagnetic field exposure reported effects on the circadian production of melatonin; (Review) J. Cel. Biochem. 51: 394-403.

Reiter RJ 1994. Melatonin suppression by static and extremely low frequency electromagnetic fields: Relationship to the reported increased incidence of cancer. *Rev. Environ. Health* 10: 171-186.

Reiter RJ, Tan DX, Poeggeler B and Kavet R. 1998. Inconsistent suppression of nocturnal pineal melatonin synthesis and serum melatonin levels in rats exposed to pulsed DC magnetic fields. Bioelectromagnetics 19: 318-329.

Repacholi MH and Greenbaum B. 1999. Interaction of static and extremely low frequency electric and magnetic fields with living systems: health effects and research needs. Bioelectromagnetics 20: 133-160.

Rommel SA and Mc Cleave JD. 1973. Sensitivity of American eels (*Anguilla rostrata*) and Atlantic salmon (*Salmo salar*) to weak electric and magnetic fields. J. fish. Res. Bd Can. 30: pp. 657-663.

Rosen LA, Barber I and Lyle DB. 1998. 60 Hz magnetic field suppresses melatonin production in pinealocytes. Bioelectromagnetics 19: 123-127. rp.Pszf.Prk. ru/hawk/URSI2002/USRI-GA/Papers/P0752.Pdf.

Rusovan A, Kanje M and Mild KH. 1992. The stimulatory effect of magnetic fields on regeneration of the rat sciatic nerve is frequency dependent. Exp. Neurol. 117 (1): 81.

Salem A, Hafedh A, Rached A, Mohsen S and Khemais BR. 2005. Zinc prevents hematological and biochemical alterations induced by static magnetic field in rats. Pharmacol. Rep. 57 (5): 616-622.

Sandyk R. 1993. Weak magnetic fields antagonize the effects of melatonin on blood glucose level in parkinson's disease. Int. J. Neurosci. 68 (1-2): 85-91.

Sert C, Akdag MZ, Bashan M, Buyukbyram H and Dasdag S. 2002. ELF magnetic field effects on fatty-acid composition of phospholipids fraction and reproduction of rat's testes. Electromanetic. Biolology and Medicine 21: 19-29.

Shedpure M and Pati AK. 1995. The pineal gland: Structural and functional diversity. Indian J. Exp. Biol. 33: 625-640. Singh M, Garbyal RS, Singh KP and Singh UP. 1995. Effect of 50Hz powerline exposed water on Hematological parameters in rat. Journal of Exp. Biology 198 (7): 1455-1467.

Solessio E and Engbretson G. 1993. Antagonistic chromatic mechanisms in photoreceptors of the parietal eye of lizards. Nature 364: 442–445.

Strand JA, Abernethy CS, Skalski JR and Genoway RG. 2005. Effect of magnetic field exposure on fertilization success in rainbow trout, *Salmo gairdneri*. Bioelectromagnetics 4: pp. 295-301.

Svedenst BM and Johanson KJ. 1998. Leukocytes and micronucleated erythrocytes in peripheral blood from mice exposed to 50-Hz or 20-kHz magnetic field. Electromagnetic Biology and Medicine 17: pp. 127-143.

Tablado L, Perez-Sanchez F and Solar C. 1996. Is Sperm motility maturation affected by static magnetic fields. EHP 104 (11): 1212-1216.

Tanski A, Formicki K, Korzelecka-Orkisz A and Winnicki A. 2005. SpatialOrientation of fish embryos in magnetic field. Electronic Journal of Ichthyology. 1: 21-34, 21.

Tenforde ed TS 1979 Magnetic field effect in biological system; *Plenum press, New York –London.*

Tesch FW, Wendt T and Karlsson L. 1992. Influence of geomagnetism and salinity on orientation of the eel *Anguilla anguilla L.*, as evident from laboratory experiments. Ecol. Freshwat. Fish. 1 (1): pp. 52-60.

Touitou Y, Selmaoui B, Lambrozo J and Auzeby A. 2002. Evaluation of the effect of magnetic fields on the serection of melatonin in humans and rats. Circadian study. Bull

Acad. Natl. Med. 186 (9): 1625-39, discussion 1639-41.

Tricas TC. 2001. The neuroecology of the elasmobranch electrosensory world: why peripheral morphology shapes behavior. Environmental Biology of Fishes 60: 77-92.

Ubeda A, Leal J, Trillo MA, Jimenez MA and Delgado JM. 1983. Pulse shape of magnetic fields influences chick embryogenesis. J. Anta. 137 (Pt3): 513-36.

Uzuka K. 1934. Some notes of the behavior of the catfish, *Parasilurus asotus*, as seen through the responses to weak electric current. Sci. Rep. Tohoku Imp. Univ. Ser. 48: 369–381.

Vallejo D, Sanz P and Picazo ML. 2001. A hematological study in mice for evaluation of leukemogenesis by extremely low frequency magnetic fields. Electromagnetic Biology and Medicine 20: pp. 281-298.

Van de Kamer JC. 1965. Histological structure and cytology of the pineal complex in fishes, amphibians and reptiles. Prog. Brain Res. 10: 30-48.

Varanelli CC and Mc Cleave JD. 1974. Locomotor activity of Atlantic salmon parr (*Salmo salar*) in various light conditions and in weak magnetic field. Anim. Behav. 22: pp 178-186.

Vollrath L. 1979. Comparative morphology of the vertebrate pineal complex; Prog. Brain Res. 52: 25-37.

Walker MM. 1984. Learned magnetic field discrimination in yellowfin tuna, *Thunnus Albacares*. J. Comp. Physiol. 155A: pp. 673-679.

Walker MM, Diebel CE, Haugh CV, Pankhurst PM, Montgomery JC and Green CR. 1997. Structure and function of the vertebrate magnetic sense. Nature. 390: pp. 371-376.

Warnke U. 2006. Magnets to overcome pain: The new healing method (Internet sources)

Wilkens LA and Hofmann MH. 2004. Behavior of animals with passive, low frequency electrosensory systems. Name /sv04/24236_u07, pp. 229-263.

Wilkens LA and Hofmann MH. 2004. Behavior of animals with passive, low frequency electrosensory systems. Name /sv04/24236_u07, pp. 229-263.

Wilson BW, Matt KS, Morris JE, Sasser LB, Miller DL and Anderson LE. 1999. Effects of 60 Hz magnetic field exposure on the pineal and hypothalamic-pituitary-gonadal axis in the Siberian hamster (Phodopus sungorus). Bioelectromagnetics. 20, pp. 224-32.

Wilson BW, Stevens RG and Anderson LE. 1989. Neuroendocrine mediated effects of electromagnetic-field exposure: possible role of the pineal gland; Pubmed indexded for medline. Life Sciences 45(15):1319-1332.

Wiltschko R and Wiltschko W. 1995a. Magnetic orientation in animals. Spinger verlag Berlin

Wiltschko R and Wiltschko W. 1998. Pigeon homing: Effect of various wavelengths of light during displacement. Naturwissenschaften 85: 164–167.

Wiltschko W and Wiltschko R. 1995b. Migratory orientation of European robins is affected by the wavelength of light as well as by a magnetic pulse. J. Comp. Physiol. A 177: 363–369.

Wiltschko W and Wiltschko R. 1999. The effect of yellow and blue light on magnetic compass orientation in European robins, Erithacus rubecula. J. Comp. Physiol. A 184: 295–299.

Wiltschko W, Munro U, Beason RC, Ford H and Wiltschko R. 1994. A magnetic pulse leads to a temporary detection in the orientation of migratory birds. Experientia 50: 697-700.

Wiltschko W, Munro U, Ford H and Wiltschko R. 1993. Red light disrupts magnetic orientation of migratory birds. Nature 364:

525–527.

Wiltschko W, Wiltschko R and Munro U. 2000a. Light-dependent magnetoreception: Does directional information change with light intensity. Naturwissenschaften 87: 36–40.

Wiltschko W, Wiltschko R and Munro U. 2000b. Light-dependent magnetoreception in birds: the effect of intensity of 565–nm green light. Naturwissenschaften 87: 366–369.

Winnicki A, Korzelecka-Orkisz A, Sobocinski A, Tanski A and Formicki K. 2004. Effects of the magnetic field on different forms of embryonic locomotor activity of Northern pike, *Esox lucius*. L. Acta Icthyol. Piscat. 34 (2): 193-203.

Wurtman RJ. 1980. The pineal as a neuroendocrine transducer. In: Krieger DT, Hughes JC, eds. Neuroendocrinology Sunderland, Massachusetts: Sinauer Associates, Inc., 102-108.

Yano A, Ogura M, Sato A, Sakaka Y, Shimizu Y, Baba N and Nagasawa K. 1997. Effect of modified magnetic field on the ocean migration of maturing chum salmon, *Oncorhynchus keta*. Mar. Biol. 129 (3): pp. 523-530.

Yellon SM. 1994. Acute 60 Hz magnetic field exposure effects on the melatonin rhythm in the pineal gland and circulation of the adult *Djungarian hamster*. J. Pineal Res. 16: 136-144.

Zare S, Hayatgeibi H, Alivandi S and Ebadi A G. 2005. Effect of whole-body magnetic field on changes of glucose and cortisol hormone in Guinea pigs. American Journal of Biochemistry and Biotechnology 1 (4): 217-219.

Zimmerman S, Zimmerman AM, Winters WD and Cameron IL. 1990. Influence of 60-Hz magnetic fields on sea urchin development. Bioelectromagnetics 11 (1): 37-45.

Zimmermann B and Hentschel D. 1987. Effect of a static magnetic field (3.5T) on the reproductive behavior of mice, on the embryo and fetal development and on selected hematological parameters. Digitale Bilddiagn 7 (4): 155-6.