

Magnetism and Human Body

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Abstract: *This is a short review article on how a very significant material-property magnetism is connected to animal-perceptions in general and especially to human perceptions accompanied with mentions of some remarkable experiments and results and studies and investigations on physiological and psychological effects of magnetism in elementary level.*

Keywords: Magnetism, Human Physiology, Psychology, Magnetic Field

1. Introduction

“A magnet to your cranium quick, This bamboo will deflect it. If your head reels, here comes a brick; dynamics should correct it.” It is a portion of a poem of Sukumar Ray, originally in Bengali and translated into English by Prof. Sukanta Chaoudhury where a magnet is told to be put on the head of a man. It is solely the magnet which, without the help of anything else can turn the head of a man. A story about the temple of Jagannath Deva in Puri Dham, Orissa goes like this: A huge magnet of gigantic volume and therefore extraordinarily powerful was made hanging from the roof of the temple in remote past. This magnet, as is told by some people, by its strong attracting power used to create trouble in dislocating huge iron chains of docked ships in the shipyard nearby in British rule-period. Getting annoyed with this happening the British navy persons including captains and others suddenly attacked the temple on a day and broke apart the magnet from the top of the temple and took away it with them. It is now-a-days heard that that magnet is kept well-preserved in the British Museum.

What is a ‘Magnet’ really? Ordinarily crystalline solids and within some specific conditions some liquid and also some gaseous material, that exhibit their own physical property of attraction, repulsion and directionality are collectively known as ‘Magnet’. A Magnet attract iron and similar materials while repel the similar pole of another magnet. While kept hanging freely with a cotton string tied exactly at the middle of a bar-magnet it settles in a particular orientation. If turned a little the hanging horizontal bar-magnet after a little time with rotational oscillation again settle to be at rest along that very particular orientation which it took earlier.

This particular property of a permanent magnet of aligning along a particular direction is called its directive property.

Who discovered Magnet?

It is told that about four thousand years ago there lived a Greek shepherd named ‘Magnese’ in a village named Magnesia in Northern Greece who one day while grazing cattle on a stony area got stuck with his boots’ iron nails underneath on a black stone like object there. He then could not move his legs by applying normal force as one usually exerts. This fact surprised him and he then dug out that black stone from soil. As because he felt his leg heavy after getting stuck at the black stone, he named it ‘Load-Stone’ to mean

as if some extra load was given to his leg. Actually, there were paste-attached two iron plates underneath the pair of boot he wore which got stuck at being strongly attracted by that very stone which later was recognized as a ‘Magnet’ after the name of its discoverer and also of the place of discovery i, e. Magnese and Magnesia. Famous writer ‘Plini’ of Rome described ‘Magnet’ in comparison with power of enchantment or a magical power. It is also told that perhaps the Vikings of Scandinavia, at about 1000 AD were the first to use Magnetic needle as navigational direction- finder or compass. In ancient India (Bharat Barsa) at about 1200 AD ,in the chapter ‘Rasarnava’ of one most sacred source-book ‘Patala’ the characteristic features of magnets , their effects and various properties were all described in great details and on the basis of that Magnets or rather the properties of Magnetism were categorized as the following:

In original Sanskrit pronunciation

“Bhramakang Chumbakang Chaiba Karshakang Drabakang
tatha Ebong Chaturbidhang KantangRomakantang Cha
Panchamam I Ekadwitrichatuh Pancha
Sarbatomukhamebatat Peetang, Krishmnang Tatha Raktang
Tribarnang Syat Prithak PrithakII”

The underlying meaning of the above sloka is as follows;

‘Brhamanakaraka’ means ‘Mover and Rotator’, ‘Chumbakang’ means ‘Kissing i.e. weak Magnet’, ‘Karshakang and Drabakang’ mean respectively ‘ Attracting and Lightening (Dissolver) i.e. Repulsive’ ; These are the four types Magnet- Body-Property’ along with a fifth one ‘Romo kantang’ yielding a totality of five varieties which presumably refers to ‘Ferrimagnetisms, Para magnetism, Ferromagnetism, Diamagnetism and Anti-ferromagnetism respectively of today’s science. And each of these five categories again have six open-face sub- categories; namely Monopolar, Dipolar, Tripolar, Quadripolar, Quintipolar and Multipolar. Whether these sub-categories were to mean various type of crystal structure or Domain- Structure cannot be clearly understood yet. Magnets used to be marked with three distinguishing colors, yellow, red and black.

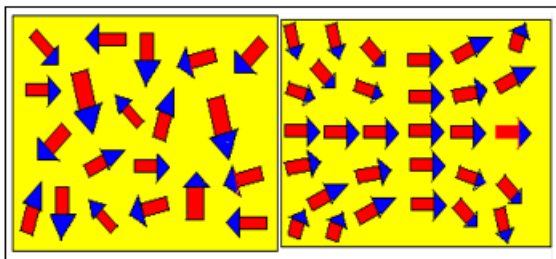
At about 1000AD, as story goes, the magnetic devices were technically modernized especially for navigational purpose. Basic physical properties of magnet are collectively known as ‘Magnetism’. Magnets are mainly of two types; artificial and natural. Based on various aspect of magnetism materials are classified into two groups; Magnetic materials (materials that can be influenced by any natural magnet or by any other similar means and be made a magnet) and nonmagnetic

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materials (which are not influenced by any magnet or similar means). How were the natural magnets produced was known after the discovery of actual reason behind magnetism at microscopic scale. One of the artificial methods of transforming a magnetic material into a magnet, mechanical sliding was discovered prior to the discovery of its real explanation at microscopic level. Among all the ferromagnetic element 'Iron' is the most prominent one whose nucleus is very much stable and the element forms metallic crystal. One of its principal physical properties (as obtained from experience) is to undergo magnetization while placed within strong electrical discharge (refer to the detective mystery story 'The Royal Bengal Mystery' of Satyajit Ray). But that ferromagnetic material transformed into magnet if is treated with huge jerk repeatedly over quick succession or with collision with rigid body or be heated sufficiently behaves like a paramagnet showing much weaker magnetism. We know from the kinetic theory of matter 'heat' is the collective manifestation of molecular kinetic energy. Rise of temperature is caused by rise in the total heat-content of the object considered which again is caused by the preceding rise in the random chaotic motion of the multitude of molecules in the bulk of the material. As the phenomenon of magnetization is nothing but the alignment of molecular magnets in a particular direction it means an orderliness which is obviously countered by the random motion of the molecules. [Hence rise of temperature cause decreased magnetism through derangement of molecular magnets that are popularly known as Weber-elements]. Weber, as is widely known, was the first on the globe to explain magnetism on the basis of distribution of molecular magnets in matter and to show respect this molecular magnets are called sometimes 'Weber-elements'.



Starting from theory statical electricity due to Gauss and Coulomb and then passing through successive discoveries and works of Benjamin Franklin, Louis d'Galvani, Volta, Gilbert, and with the advent of Ohm and Ampere theory of current electricity was established. Weber extended the theory of magnetostatics which again was further modified by Tesla. Following the similar arguments as that of statical electricity due to Gauss and Coulomb the fundamental laws of statical magnetism was derived almost empirically. Magnetic pole, magnetic force, magnetic field-intensity, magnetic moment, magnetostatic and magnetodynamic potentials and potential energy, are the most important physical properties and variables in the theory of magnetism. After all these came the famous experiment of Oersted on the effect of current electricity on magnetic needle which presumably revealed for the first time in the world the fact that where there is an electric current there is a magnetic field around it appreciable up to a certain extension of space. Following this Laplace established an equation depicting

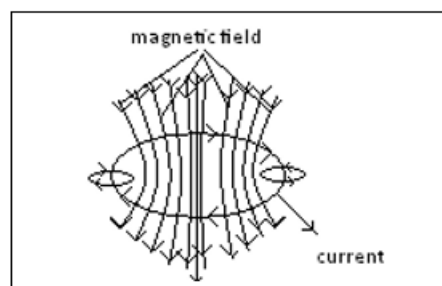
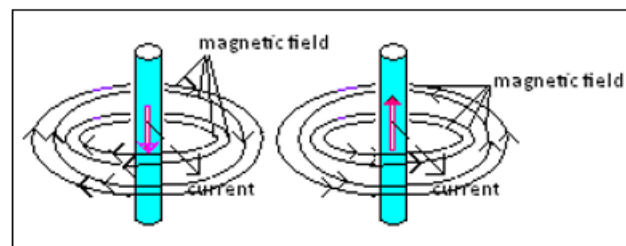
beautifully the qualitative and quantitative signature of this truth.

$$d\vec{H} = \frac{i d\vec{l} \times \vec{r}}{r^3} \quad \left\{ \text{In magnitude only } dH = \frac{idl \sin \theta}{r^2} \right\}$$

where 'dH' is the magnitude of intensity of magnetic field (= the magnetic force experienced by magnetic pole of unit pole-strength) at r-distance apart from a current 'i' being carried through 'dl' length of a flow of electricity. The vector-algebraic equation of-course has greater scientific implication in regard to the direction of magnetic field thus produced as this is a vector quantity. Ampere then reformulated with a view of its much easier application in his famous circuital law for a closed loop circuit in integral form.

$$\oint \vec{B} \cdot d\vec{l} = \left(\frac{\mu_0}{4\pi}\right) i$$

This theory reveals the experimental fact a straight-linear electric current produces a closed-loop magnetic field around it where as closed-loop electric current produces an axial magnetic field which is also the other way round (Fig. below);



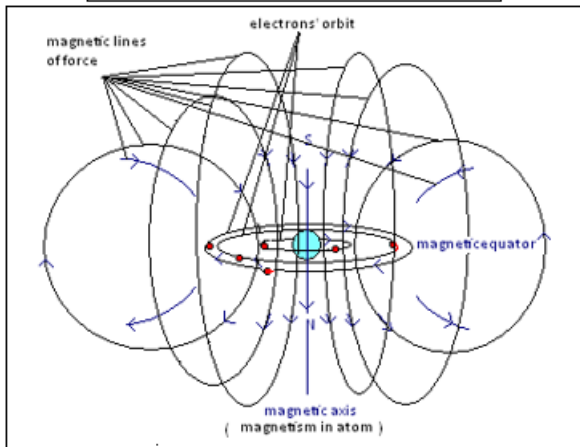
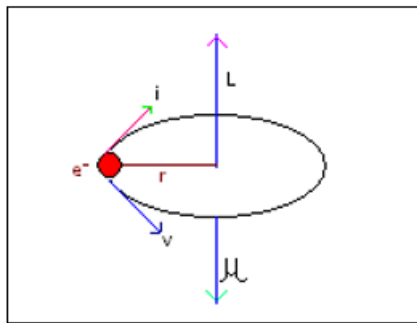
The direction of magnetic field thus produced is always perpendicular to the plane of the electric current. It is therefore the very fact which in the 'History of Science' reveals out that electrical charges are more fundamental an entity which is the source of statical electricity. Electric charges in motion produces both moving electric field and magnetic field. Therefore, the root cause behind the magnetic field is electric current (flow of charged particle constitute 'Drift Current' and 'Diffusion Current' while moving electric field constitute what is known as 'Displacement Current').

After having known the fact that within an atom there reside electrons which are negatively charged particle and they revolve in a closed orbit around the atomic nucleus it is possible with the help of Laplace's as well as Ampere's theory to explain molecular and also atomic magnetism. Electrons within atoms revolving in circular or elliptical orbit being confined as closed electrical current-loop

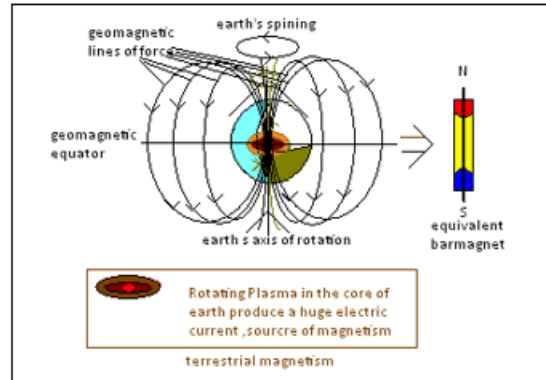
produces each a resultant permanent magnetic moment as well as magnetic field. For a single such electron revolving round an atomic nucleus within an atom having rest-mass equals to ' m_0 ', electrical charge ' e ' and angular momentum equals to ' \vec{L} ' the corresponding magnetic moment of thus produced magnetic field is given by,

$$\vec{M} = -\left(\frac{e}{2m_0}\right)\vec{L} = -\left(\frac{e\hbar}{2m_0}\right)\left(\frac{\vec{L}}{\hbar}\right) = -\mu_B\left(\frac{\vec{L}}{\hbar}\right)$$

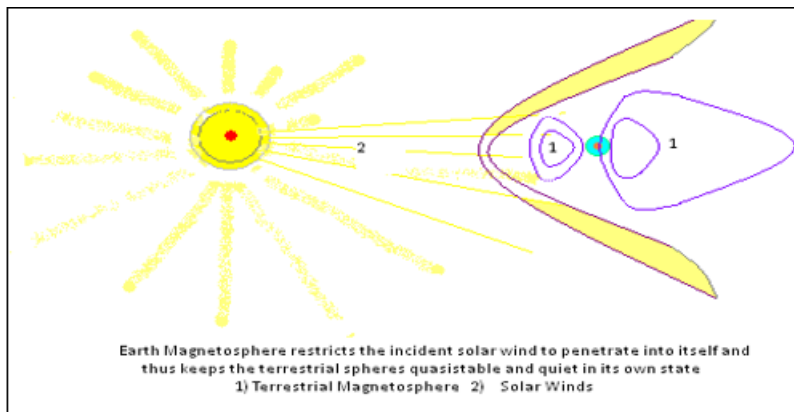
where, $\mu_B = \left(\frac{e\hbar}{2m_0}\right)$ is called the Bohr-Magneton and $\hbar = -\left(\frac{h}{2\pi}\right) = \frac{\text{Planck's constant}}{2\pi}$.



Space spanned by some kind of influence is called 'field' and space spanned by magnetic influence is called '*Magnetic Field*' the existence of which is detected by means of its interactions that can happen only with magnetic materials having molecular magnets with non-zero magnetic dipole moments or with electric current. Explanation of Geomagnetic field goes alike that of atomic magnetism.



In the deep interior of the Earth the average temperature is very high as up to about 5000° C and consequently all the material-contents there are in plasma state (excited ion-clouds). The plasma-core of earth rotates along with the Earth in its diurnal motion (axial rotation of earth) and thereby produces a huge electric current-circulation with earth's core. As a consequence, a magnetic field around the earth up to a far distance above the Earth is developed (Geomagnetic field). According to Biot-Savart-law the magnetic field ' \vec{B} ' produced by an electric current ' i ' in a circular loop at its center (radius of loop being ' r ') is given by $B = \frac{\mu_0 i}{2r}$. Similarly magnetic field due to an atomic electron at its center is $B = \frac{\mu_0 Zev}{4\pi r^2}$ where Z is the atomic number of the atom and v is the average orbital speed of the electron. The approximate average value of intensity of Geomagnetic field is found to vary from about 0.26 Gauss at equatorial mean sea-level to about 0.62 Gauss at polar mean sea-level while usual field intensity of an ordinary magnet available in the market near it is approximately 70 to 100 Gauss. This fact reveals that relatively the Geomagnetic field intensity is extremely low. But any terrestrial object or living body undergoes life-long sustained interactions with this Geomagnetic field however weak it may be and this very long-sustained geomagnetic interaction may yield any good or bad effect on that. It is from our common experiences we find that if a tamarind seed gets scooped by chance under the concrete floor at the time of its construction after a few years the seed germinates under the concrete surface and its tender trunk becomes somehow able to break open the concrete floor to move into open air above. If we collect that tender sapling in our hand and give a little pressure it immediately breaks. This means that slow but steady growth of baby plant means addition of molecules to its body from within to grow outside occupying some space and in course of doing that little force is applied to any substance that surrounds it. But continuous long-sustained hammering of those excess molecules due to their normal kinetic temperature on the surrounding wall or cover makes the cover-molecules fastened reaching elastic fatigue that produces ultimately breakage of surface. In another similar example we know that photograph of objects become unclear when exposed to light for little time which again becomes blackened or darkened while exposed to light for longer time. Therefore, the interaction-time has a significant role to play in producing intensive effect.

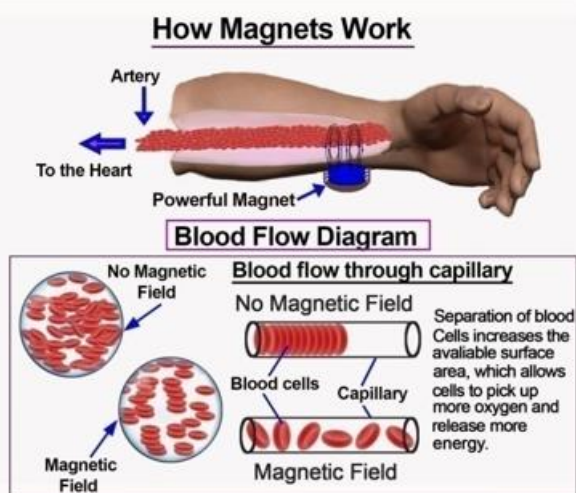


Extraterrestrial magnetic field, according as per its strength causes Geomagnetic field-structure to change. We have already known that Geomagnetic field is produced due to diurnal motion of Earth along with its plasma-core. Similarly, all cosmic bodies with plasma-sphere anywhere within its body that rotates, be it massive planet or stars have got their individual own magnetic field. In case of stars the average surface-temperature is as high as five to ten thousand degrees Celsius and a little thermal imbalance in their respective plasma-spherical surfaces produce vortices which in turn produce magnetic field. As for an example our solar magnetic influence compels our Earth's magnetic field structure to obtain a typical shape, approximately that of a burning flame and cosmic rays from extraterrestrial space mostly get trapped in that peculiarly shaped terrestrial magnetosphere giving rise to what is known as Van-Allen-Radiation-belt with a shape that matches with the ionosphere of Earth. How does the violent solar magnetic storm affect our terrestrial features being so long away have already been perceived a short time ago causing frequent disruption in our global internet system eventually. This combined electric and magnetic influence is as if far-reaching influence that pervades throughout the whole universe and that renders all objects and events in even the farthest away remotest corners of this infinite universe interconnected. A star is viewed by means of such waves that are evolved and progressed through the electromagnetic field-continuum that exists between the star and the observers. Origin of magnetic field was known and with the formulation of Lorentz-Force $\vec{F} = e(\vec{E} + \vec{v} \times \vec{B})$ the trajectory of a charged particle in a combined electric and magnetic field could be traced. This equation has multifaceted applications in our life both naturally and artificially. It is the equation which explains how the spread-out terrestrial magnetosphere helps us live long by indirectly decreasing the death-rate of vital cells of our vital physiological organs through collisions and violent interactions with high-energy cosmic-ray particles. In persuasion with this very equation comes the well-known Faraday's law and Lenz's law of electromagnetic induction. The essence of this that continuously altering magnetic induction induces in turn an electro-magnetic force in its neighborhood which is given by $e = -\left(\frac{d\phi}{dt}\right)$ and the emf is produced in such a manner so that it opposes the cause of its evolution i.e. the alteration of magnetic induction. This equation is a very powerful equation because it gives on one hand the basis of Alternating Current (A.C.) and on the other hand an important supplement to the em-wave theory. Discovery of alternating current is one of the most

significant revolutions in the history of human civilization. When this emf is produced within a conductor it will induce a secondary current which in turn causes a magnetic field to evolve which will oppose the original inducing magnetic flux-change. Considering altogether all the formulae discussed above and following a formalism with the help of differential calculus a set of four equations was formulated and solved and with that was discovered the apparently time-defying truth the theory of electro-magnetic wave ushering in a new era called Modern Age. The person behind all these great works was none other than James Clerk Maxwell whose discovery is the second Big-Bang in the history of science. Following this came shortly another the third Big-Bang and that is 'The theory of Relativity' of Einstein. Frank Hertz established experimentally the essential truth of Maxwell's theory by observing the em-wave in reality and after that Prof. J.C.Bose from Calcutta and Marconi from UK simultaneously discovered radio-wave and radio-wave producer and receiver machines. Sir J.C. Bose, being both a biologist and a physicist became able to study the influence of such radio-wave and thought about the possible inclusion of living cells in this process. For understanding the influence of magnets and magnetic field on the living beings and especially on the animals it is primarily necessary to have some basic knowledge about the ingredients and structural characteristics of the body of living beings, about all organs and functional activities of them. Among all the elements iron, cobalt and nickel are Ferromagnetic (meaning electrical conductor and magnetically susceptible), chromium is Anti-Ferromagnetic material. Besides these, except aluminum, oxygen, tin in eleventh to eighteenth column of periodic table including hydrogen and beryllium all other elements are Diamagnetic. On the other hand aluminum, tin and oxygen and other elements except those mentioned above are all Paramagnetic. The main material content which the body of human beings and of other alike animals are constituted of includes carbon, calcium, hydrogen, oxygen, nitrogen, phosphorus, sulphur, sodium, potassium, magnesium and chlorine etc.

Most of these are in the form of compound, some in the form of element and the rest are in ionic state. The elements present in ionic and in other form within the molecules of compounds undergo substantial change of chemical properties yet little change in the so to say purely physical properties, especially electromagnetic properties in the bulk. For an example the main content of human blood the hemoglobin, the hem-group of which consists of iron as the

main content; This iron, we know is a Ferromagnetic material that responds very actively and instantaneously to an external magnetic field. That's why hemoglobin of human blood too is influenced by strong external magnetic field yielding subsequent changes in its flow-pattern (Fig.). Alterations in physicochemical states, structures and activities of some basic constituents of human body affects different physiological and anatomical mechanisms in various ways and none the less also the psychological states through subsequent changes in neuro-transmissions and thenceforth psychiatric processes as well. Although 'Mind' the central object in psychology has yet no materialistic interpretation the existence of such a non-material entity is beyond doubt. There are many experimental evidences that among all external stimuli that influence human psychology magnetic field is worth-mentioning.

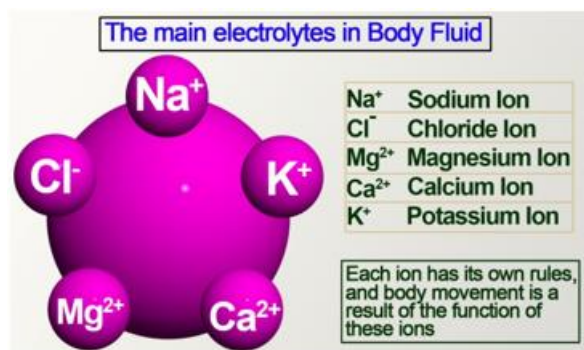


In case of other inferior animals too this thing happens to be observed. For an example a cat within the influence of strong magnetic field gets hallucinated and become indifferent to catch its favorite preys like rat. That the external magnetic field influences the functioning and processes both physiological and psychological to an appreciable extent have left us with quite a large number of evidences. About 200 years ago Dr. Mesmer told to advocate the idea that magnetic field of human body, by means of controlling the various fluid-flow within human bodies keeps most of the physiological processes to function normally. External magnetic field do affect the internal magnetic field of human body. It also affects the different types of feelings and perceptions. However external magnetic field can have influence on the body and mind because of the fact that there is a body's own internal magnetic field. The two main sources of body's internal magnetic field are

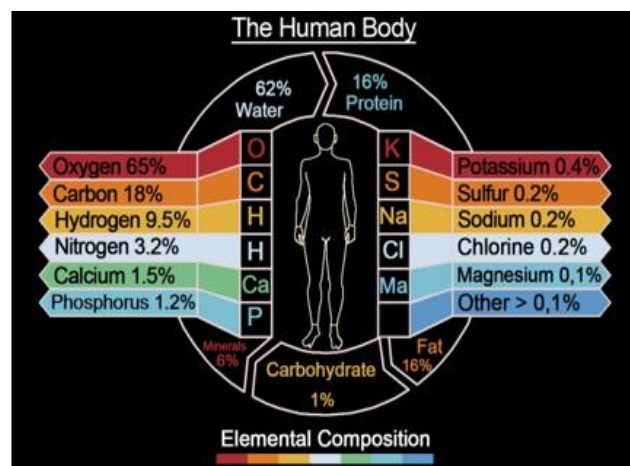
- Normal flow of electric current within body, especially human body (though of low magnitude)
- Presence of ferromagnetic materials within human body.

Main ionic components of electrolytic materials within human body, by means of successive contraction and expansion of stimulating tissues like muscle and nervous system produce a varying electric current of small amount. Due to this electric current an internal magnetic field of low intensity is produced within human body. The magnetic field thus produced at and around human heart and consequently

around shoulders can be measured through ECG and MCG. Likewise, the electric flow and the magnetic field at and around human brain can be measured by means of EEG and MEG. Normally electric current flows within human body mainly in nervous system and the emf required to produce current is found to be generated within the concerned nerve-cells.



Various types of positive and negative ions and electrolytes present on the two sides of intra-cellular and cell-internal membranes undergo in bulk a difference of pressure due to successive contraction and expansion of the tissues of the nerve-cells and nerve-muscles which in turn immediately causes an abrupt change in the superficial densities of charge carriers throughout the whole volume around and thus produce an electromotive force (emf) there.



Membrane-potential is given by $e.m.f. = 61 \log \frac{Conc.(I)}{Conc.(II)}$

where

Conc. (I) is the ion-concentration inside membrane-wall and *Conc. (II)* is the ion-concentration outside membrane-wall.

The mean

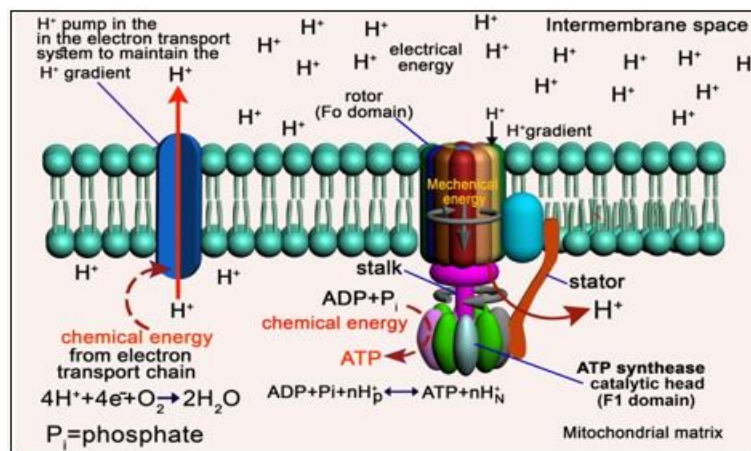
e.m.f. produced within all nerve-cells within a human body has been found out using the above equation to be about 86 millivolts.

More accurate measurement with the help of precision electronic instrument shows that this e.m.f. actually varies between 60 to 110 millivolts.

Polarization and depolarization within cell-wall membrane and cell-internal membrane plays the vital role in transferring electric potential resulting in the generation of e.m.f. This transfer occurs by means of carrying of signal which is called an impulse (Nerve-impulse). That signal

manifests itself in the form of electrical or electromagnetic pulse. It has been found that a long nerve-fiber can carry at a time a maximum of about two thousand five hundred signal-waves per second. To keep nerve-materials away from being overactive and extreme permeable it is urgently necessary to maintain a uniform moderate concentration of ions through

an all-round coordination within the whole body. In the Central Nervous System within human body the longest nerve thread that runs is Spino-cerebellar thread or fiber which carries an impulse or signal waves at the speed of 140 meters per second.



Data-table relating to signal-waves or impulses through nerve-fibers of different mammals

Class of Fibers	Mean radius of Fibers	Transmission speed	Peak-value Retaining time	Post-negative-action-potential Retaining time	Post-positive-action-potential Retaining time	Action
Series	(μm)	(m/sec)	(millisec.)	(millisec.)	(millisec.)	
A(α)	13-22	70-120	0.4-0.5	12-20	40-60	Motor
A(β)	8-13	40-70	0.4-0.6	---	---	Touch
A(γ)	4-8	16-40	0.5-0.7	---	---	Touch
A(δ)	1-4	5-15	0.6-1	---	---	Sharp pain or shrill soreness
B	1-3	3-14	1.2	Nil	100-300	Preganglionic Autonomic
C	0.5-1	0.5-2	2	50-80	300-1000	Ordinary pain or soreness, warm-cold sensation, post- Ganglionic spontaneity

Estimating the characteristic Current flow through an ion channel

We use Fick's law for the flux : $J_z = -D \frac{\delta C}{\delta z} \approx D \frac{\Delta C}{L}$

A linear profile of concentration satisfies the steady-state diffusion equation: $C(z) = C_{out} - \frac{(C_{out} - C_{in})}{L} z$

Units of flux are $\frac{\text{number}}{\text{area} \times \text{s}}$; current is $J \times A = J \times \pi r^2 = D \frac{\Delta C}{L} \pi r^2$

$D \approx 1000 \frac{\mu\text{m}^2}{\text{s}}$ for ions

Membrane thickness, $r \approx 4 \text{ nm}$

Channel radius, $r \approx 1 \text{ nm}$

For ions characteristic $\Delta C \approx 10 \text{ mM} \approx 10^7 / \mu\text{m}^3$

$$J \times A \approx 1000 \frac{\mu\text{m}^2}{\text{s}} \times 10^7 \mu\text{m}^{-3} \times 3 \times 10^{-6} \mu\text{m}^2 / \underbrace{4 \times 10^{-3} \mu\text{m}}_L \approx 10^7 \text{ s}^{-1}$$

It is very essential for fluids in the intracellular, intercellular and extracellular region to have difference of proton-concentration for maintaining various type of equilibrium or balance like acid-base balance within human body. This proton-balance is obviously an ion-density related property. The specific range of value of the hydrogen-ion concentration i.e. the proton-concentration, as has been calculated and indicated in the adjacent figure should be

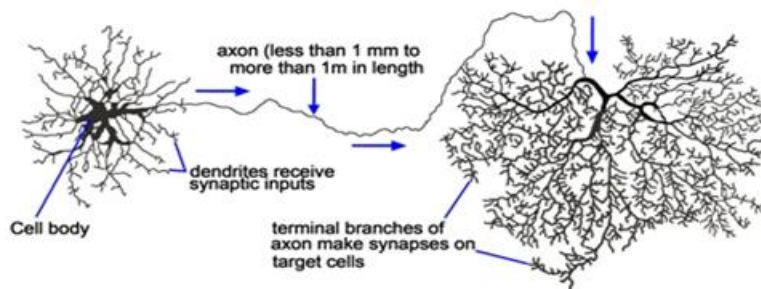
maintained at per for the normal human physiological activities.

On the basis of Fick's law pertaining to the nerve-fiber-conduction-model a probable value of electric current in the ion-channels can be calculated. Nerve-cells mutually communicate signals to each other through a long hollow cylinder like object called 'Axon'. This action is electrically active. The primary function of these axons is to transfer

pulse signal from cell to cell. Messages or results of interaction between external stimuli and sense-organs' perception- center are carried to brain through this type of signal-transmission and in return consequently regenerated brain-waves run immediately to muscle tissues that yields motion of organs and other related mechanical work. In this calculation nerve-fibers or so to say, axons are considered model of coaxial cylindrical capacitor which the effective value of emf is determined of. Charges on ions are assumed to be moving along the radii of those axons and the consequent signals are assumed naturally to be carried with the transverse wave along the axis of the axon- tubes.

Specific properties of neurons similar to those of a signal-carrying tube:

- 1) Through cytoplasm neurons can transfer electrical charges.
- 2) Due to its high resistance and diffusion of charges through pores on the wall of diaphragm axon-like cable properties are weak.
- 3) One axon-signal does not travel throughout the whole length of it.
- 4) Each axon-signal causes secondary signals to evolve that transfuse into the next region.

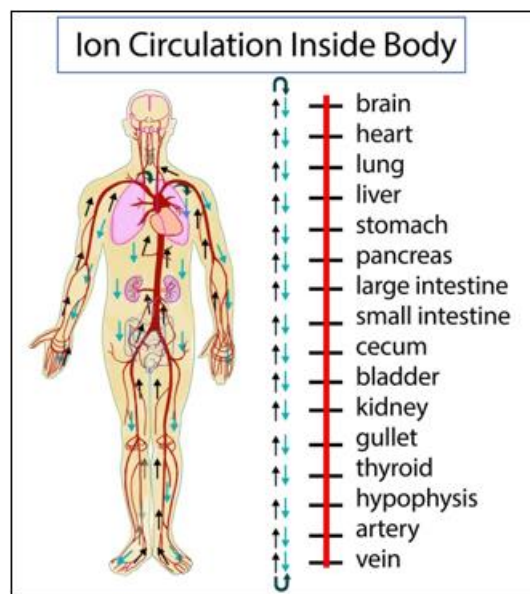


That means the average human body-magnetic field intensity is 10^{-5} to 1 in ratio with terrestrial magnetic field intensity. Human blood itself is macroscopically electrically neutral yet it carries so many charged particles or ions while flowing and containing hem-group blood-cells behave like paramagnetic materials. Besides such ion-flow as the root of human body-magnetic field there are other sources such as magnetic material like Fe_3O_4 within human body. This ferrite or magnetite has been observed to be present in highest proportion lung. It is found that normally the body of a matured man containing approximately 4.5 grams of iron in totality of which 3gms are in the form of hemoglobin. The rest 1.5 gm. of iron is the form of ferrites. All these magnetic materials may be magnetized by the influence of external magnetic field and be again be demagnetized too by the internal heat (feverish condition accelerate such demagnetization) and pressure-difference. External magnetic field affects human body basically in two ways;

- a) Interaction with the internal magnetic field produces excess pressure directly through impinging with force or torque.
- b) The internal magnetic materials through induction and thence after interacting with them again a pressure-excess through force or torque.

If action-signals are thought to be electrical current neurons may be thought to be in either of the two following states;

- 1) Resting state: Electrical potential difference between the inside and outside of a neuron is approximately 70 millivolt. Na^+ ions emerge from cells while K^+ ions enter into the cells. Ions do naturally come out of cells through diffusion rendering a potential- difference between the inside and outside of a cell. Inner side of a cell becomes relatively more negative.
- 2) Interacting State or Dynamic State: Nerve signals are carried through specific cells and get dispersed into different parts of the body. Electrical excitation created through action-potential helps respond to stimuli and in presence of specific ion-channels action-potential is transferred along plasma-membrane. Nervous system is a common name in all neuronal processes involving axons or dendrites. Signals are the communicating means between two neurons or one neuron and an influencer. In such dendritic process it is within synapse where signal-waves are transmitted through neurons that carry messages to cells. The magnetic field or so to say magnetic induction produced due to above-mentioned electrical processes has been found approximately to vary from 10^{-10} Gauss to 10^{-5} Gauss (10^{-14} Tesla to 10^{-9} Tesla) where as Geomagnetic field on Earth's surface is approximately 0.5Gauss.



This excess pressure, on one hand can physic chemically produce an alteration in body-dynamics as well as on the other hand can yield, to some extent substantial change in all over physiological and psychological system in the long run. Magneto-gradiometers are mainly of two types; i) Fluxgate

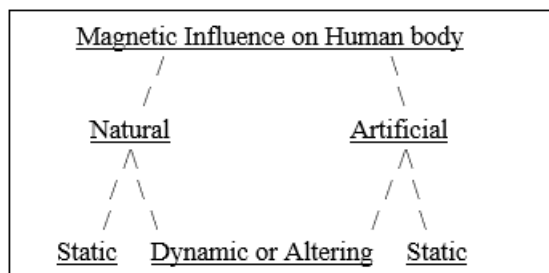
Gradiometers and ii) Superconducting Quantum Interference Device (SQUID). These devices are used to measure human body magnetic field and also with the help of these devices Magneto cardiogram (MCG) and Magneto encephalogram (MEG) can be produced which in turn help tremendously detecting various types of Cardio logical and Cerebral disorder and their immediate cause. Human body-magnetic field and the consequent effects can be classified into two; namely

- a) Magnetostatic effects caused by the permanent ferromagnetic components of human body,
- b) Continuously changing magnetic influence due to flow of charged particles through body- fluids and their interaction.

Mutual interactions among multiple magnetic fields from multiple sources affect animal body, especially human body in various ways. More than 200 years ago Dr.Mesemer announced that internal magnetic field of a body controls or guide the flow of special kind of internal fluids and when due to any reason this flow is hindered the body undergo illness. Actually, by the influence of various external magnetic field, be it naturally or artificially produced both bad and good changes of our physiological system may be resulted.

Terrestrial magnetosphere, extending up to a large altitude trap most of the high energy cosmic rays and stops them from coming to earth-surface and colliding with our body-cells completely destroying them. This acts as a shield or cover that protect us and helps us live long.

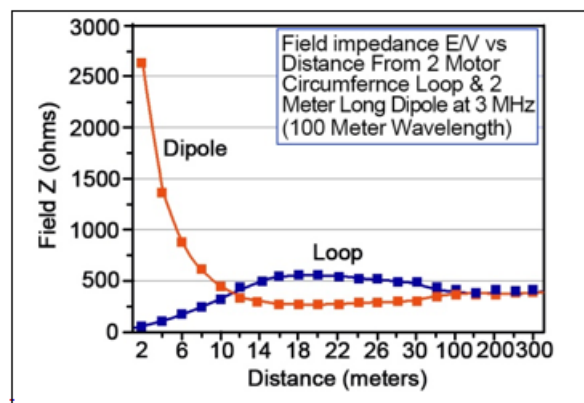
This is called magnetic shielding of earth. On the other side one may cite example of a person undergoing angioplasty and thereby having his/her heart replaced by an artificial one may receive life threat if comes close to strong magnetic field-producing device or high voltage electricity. The classification of external magnetic influencer depending on the nature and sources of them;



Among the sources of naturally occurring static magnetic field known until now the sources of highest intensity-magnetic field is 'Magnetar' which is actually a neutron star of a very rare category and its magnetic field is 1 billion times that of terrestrial magnetic field-intensity.

It is commonly told that if such a magnetar would have existed within a few light-years from our solar system the shape of atoms within our body could have changed drastically and forced polarization of molecules within our body could have destroyed the stability of molecular bulk and thereby the body-cells. Location of planets and stars too could have changed. Fortunately, enough no such magnetar is there in the far neighborhood of our solar system. Yet the

magnetic field of different cosmic bodies that exist in space from extraterrestrial to extra-solar to extra- galactic are in combination never so negligible as to be disregarded. Actually, the range of external magnetic field, its limit and period of interaction altogether determine the magnitude and nature of effects on the animal body, especially on the human body. The complex magnetospheric characteristics of our solar system gets influenced by the far extended magnetic field of our galaxy 'Milkyway' and consequently magnetic activity of its various component- sources, such as the Sun itself, Jupiter, Uranus, earth and so on undergo very slow but steady, permanent and temporary both kind of changes.



Again, solar magnetic storms as well as the waxing and waning in the number of sunspot number produces permanent (for example Van Allen Radiation Belt specially shaped like blowing candle flame) and instantaneous states in the terrestrial magnetosphere. Those influences, even though very feeble yet long-sustained can yield some kind of perceptible changes in the magnetic state of body terrestrial habitat. In the figure above graphical plot of the ratio of electric to magnetic field-intensity due respectively to a circular conducting loop of 2 meters arc-length and a 2meters long magnetic dipole receiving em wave at 3MHz frequency against distance is shown. Here it is seen that magnetic field intensity is greater within 14 to 26 meters from source in case of dipole while the same is greater within 2meters to 10 meters for circular loop. The table below shows the approximate values of static and dynamic magnetic field intensity from different natural and artificial sources from which one can apprehend the relative strength in each of the cases;

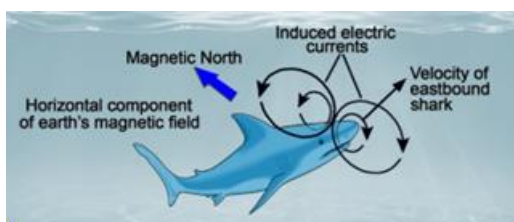
Source	Approximate Magnetic Field Strength
Neuron depolarization (imaged by MEG)	0.5 pT (5 x 10 ⁻¹³ T)
Earth's magnetic field	0.5 G (50 μT)
Refrigerator magnet	50 G(5mT)
Junkyard electromagnet	1 T
Clinical MRI scanners	0.5-3.0 T (typical)
Research MRI scanners (human)	7.0 T - 11.7 T
Laboratory NMR spectrometers	6-23 T
Largest pulsed field created in lab nondestructively	97 T
Largest pulsed field created in lab (destroying equipment but not the lab)	730 T

Natural magnetism in our neighbourhood refers mainly to geomagnetism. The rest are somehow artificial. Magnetic field within the body of animal, especially of human beings

are utterly negligible. The microforces and micro-torques as results of different interactions between any external magnetic field, artificial or natural and the field within our body is therefore feeble. But if such interactions continue for very long time the ultimate corresponding results do not remain negligible any more. Relevantly it may be mentioned that in spite of mentioning about static magnetic field in the earlier sections in reality perfectly static magnetic field is almost a nonexistent. Whichever magnetic field we encounter in our daily life is varying due to natural motion of their sources and that's why in case of any magnetic field being perceived through interactions must be accompanied by sources' and consequent electric field too. Influence of external magnetic field within animal body including human body is propagated mainly in three ways;

i) Mechanical Transfer process, ii) Electrical Transfer process, iii) Chemical Transfer process.

In each of these cases, despite the magnitude of magnetic influence being small after a long duration such interactions produce some measurable change in the states of physiological, anatomical and even therapeutic systems within living bodies. In organic systems, due to their inherent anisotropy Diamagnetic macromolecules reorient due to the action of magnetic torque. Transparent 'Vitreous Humor', a jelly-like viscous fluid that exist within our eyes and also 'synovial fluid' present at anatomical joints of our body are influenced by external magnetic Field. Long-chain organic macromolecular systems constituted of magnetic crystal are called 'Magnetosome'. It has been observed in experiment that these magnetosomes of magnetotactic bacteria play vital role in controlling the direction of motion of bacteria. They align along geo-magnetic field towards north-pole they move down under the soil that helps them survive in muddy soil with low oxygen supply. It has also been established through experiment and investigation that using their perceptions relating to interaction of their own body-magnetic field with geomagnetic field migratory birds and fishes and other such animals determine their destinations. In those cases for magnetomechanical force one can write

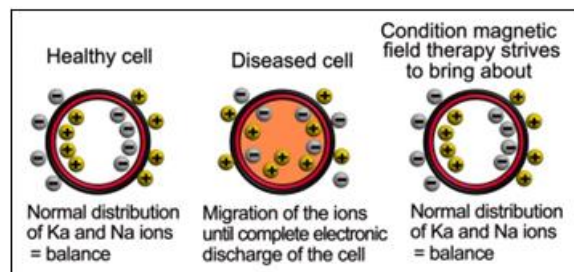


$$T = \left(\frac{\chi}{\mu_0} \right) B \left(\frac{dB}{dx} \right)$$

where χ is the magnetic susceptibility, μ_0 the magnetic permeability of free space, B the magnetic induction and $\frac{dB}{dx}$ is the magnetic field-gradient.

Time-varying magnetic field produces electrical induction following Faraday's laws which ultimately causes resulting electrical current-density $j = \pi r v \sigma B_0$ where r is the radius of circular conducting loop, B_0 the amplitude of varying magnetic induction, v the frequency of variation and σ is the electrical conductivity of animal-body-fiber carrying electrically induced field. Extra Low Frequency (ELF) em-

wave produces a very specific perception in human body as a result of which one can feel a light flash in the eye even when the eye-lids are closed. This phenomenon is known as 'Magnetophosphenes'. Such perceptions do occur for interaction-variation of a magnetic induction amounting approximately from 10 to 100 microtesla at a frequency varying from 10 to 100Hz. Among other effects like the above one resisting osteoporosis and bone-recovery, nervous excitation, electrical shock-driven loss of sense, damping of cardiac oscillations are worth-mentioning. In some literatures related to research on effects of magnetic field on human body it has been claimed that magnetic field produced due to an electrical current-density less than 10mAmp/m² can hardly be realized in practice. In those literatures it has also been claimed that static magnetic field less than 2 tesla cannot affect appreciably because, as they explain, there are many regenerative physiological processes within human body that help recovery from degenerative small perturbations produced by interactions with such external magnetic field. In some other such research papers researchers blame a few factors for observing such unresponsive state within human body towards the interaction with external magnetic field. For example, they say that micro-magnetic dipoles being so small remain extremely close to each other and thus opposite poles being so close nullify each other's' responses to external magnetic field in the bulk. Secondly performing these experiments without the help of appropriate magnetic shielding may cause some anomalous results. The different natural sources that may yield inaccuracies in such experiments through their magnetic influences are mainly atmospheric electricity, flux of cosmic rays, varying intensity geomagnetic field etc.



In reality enumerable evidences of effects of external magnetic field on physiological, anatomical, physical and psychological systems of human beings have been established in quite a large number of researches. On the basis of those results a unique branch of nonconventional medical system named 'Magneto-therapy' has been established. Scientific explanation of this system of medical practice has also been given where the results determined on the basis of theoretical modeling matches with the observed result. The figure above shows how the use of controlled external magnetic field transforms a diseased cell with ion-imbalance into a healthy cell with balanced ion-distribution. The effect of magnetic field is not confined only to the animal kingdom. It is most surprising to think of how through various successful experiments scientists have been able to discover so many surprising results on the effect of magnetic field on different plant-cells. A few of those are given below;

- 1) If the surrounding magnetic field is made to undergo repeated variation from 50millitesla to 250millitesla germination-rate for some crop-seeds get enhanced.
- 2) Controlled external magnetic field around enhances nutrition and growth of such many seedlings and saplings.
- 3) Blue-light photosensitive crypto chrome produces radical compounds that play important role of receiving magnetic influxes from outside.
- 4) Long-sustained influence of external magnetic field renders enhanced growth of roots and root-shoots in cases of some plants.
- 5) For the gradual steady evolution of terrestrial flora starting from pro-Mesozoic through Paleozoic up to present day along with factors like light, air, wind, gravitation, chemical addition and exposition, temperature, pressure, humidity etc. external magnetic field too is considered to play vital role behind.
- 6) Generally, it has been found that for plants especially the horse-shoe magnet produces little effect while strong bar magnet do produce appreciable effect.
- 7) Application of external magnetic field helps keeping straight the petiole and pedicle of plants.

On the other hand, there are interesting findings about the application of external magnetic field in cases of microorganism that are mentioned below;

- a) Strong magnetic field, while applied to for some period growth of protozoa is resisted.
- b) Reproduction rate of yeast decreases by approximately 20-30% if kept within external magnetic field of 4 Gauss for about 20 minutes. But the effect is realized on for inhomogeneous magnetic field ,not for homogeneous magnetic field. Therefore, not exactly the field-intensity but the field-gradient is responsible here.
- c) If held under the influence of 4000 Gauss external magnetic field for about 18 hours or so tumor-cell affected with sarcoma ascites gets diminished to a large extent.

At the end another interesting result of an interesting experiment is described briefly in the following section;

Effect of Geomagnetic latitude and longitude in comparison with Geographic North-South east-west direction:

Forty medical students of age group 18yrs. to 25yrs. are selected who used to sleep 8hrs. A day for 12 weeks in different directions. Checking at regular interval of after-sleep pulse-rate, systolic and diastolic pressure, serum cholesterol are made. The final results that come out are as follow:

SBP, DBP,HR and SC of students who used to sleep keeping their heads southward are low enough with a significant value of statistical weight. Such experiments should be planned and performed frequently many more times with care and precision to find out the actual truth and explanation of such results.

Sometimes static and sometimes dynamic electric and magnetic field and somewhere field- gradient do have various types of effects of different magnitude on

macroscopic to microscopic members of flora and fauna within terrestrial biosphere by little to an appreciable margin and this is an established truth. Henceforth it is urgently required for scientific community to study and investigate much more willfully and carefully such effects with the help of more sophisticated instruments with high precession and accuracy to extract the real scientific mechanism behind such effects and then to improvise through indigenously developed scientific tools, knowledge and experiences for utilizing in the benefit of the society.

Magnetism and Electromagnetism are but, in the history of human civilization the most amazing the greatest discoveries which are the prime promoter of deriving, preserving, testing, investigating, searching and gathering knowledge and experiences and at the center of all great scientific discoveries.

Acknowledgement

The author humbly and gratefully acknowledges the indirect help he obtained in consultation of different source-materials such as books, research papers, articles and open- access figures, graphs and tables etc. available free in the internet through Google search and have used them for demonstratively describing different facts and phenomena in this short review paper in order to cater an overview of an interesting interdisciplinary subject. The sources are given in the following reference.

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