Spontaneous Aggregation of Non-Living and Living Matter in Aqueous Environments Subjected to a Static Electromagnetic Field: Potential Link to the Next Step of Abiogenesis

by

Ryan D. Bidal

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Laurentian University
Sudbury, Ontario, Canada

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APPROVED/APPROUVÉ

Thesis Examiners/Examinateurs de thèse:

Dr. Blake Dotta
(Co-Supervisor/Co-directeur de thèse)

Dr. Rob Lafrenie
(Co-Supervisor/Co-directeur de thèse)

Dr. Frank Mallory
(Committee member/Membre du comité)

Approved for the Faculty of Graduate Studies
Approuvé pour la Faculté des études supérieures
Dr. David Lesbarrères
Monsieur David Lesbarrères
Dean, Faculty of Graduate Studies
Doyen, Faculté des études supérieures

Dr. Yves Bureau
(External Examiner/Examinateur externe)

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Abstract

Exposing spring water isolated in darkness to a very powerful static magnetic field for 5 days without any disruption produced a greater amount of an aggregated crystalline precipitate than water alone. These aggregated crystals seemed to have formed a network at the water's surface. This effect was not observed when using distilled water. Decreasing the volume of spring water diminished the amount of crystals produced. Placing a solution of spring water inside on an operating hot plate also produced a large amount of crystals, but these crystals resembled a powdered substance rather than a connected network. A similar effect involving the static magnetic field was also observed following a comparable paradigm using cells. A greater number of cells developed in plates of cell media exposed to the same powerful static magnetic field in the dark for 24 hours prior to the injection of cells when compared to plates of cell media not exposed to a magnet. These results, taken together along with quantitative calculations exploring the structure of the cell, suggest that electromagnetism in aqueous solutions may have played a larger role in the emergence of the organic from the inorganic, and this may have occurred by altering the structure of liquid water which subsequently influenced the organizing and structuring of the dissolved molecules within it.

Keywords

Water, crystals, static magnetic field, electromagnetism, energy, cell, aggregate, chemical bonds, abiogenesis.

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Chapter 1 – Introduction

The Earth was formed approximately 4.6 billion years ago. It is estimated that a sizeable amount of water, enough to form oceans, had accumulated by roughly 4.5 billion years ago (Chan et al., 2018). Around 3.7 billion years ago, the earliest life form could be found. (Rosing, 1999; Ohtomo et al., 2014; Pearce et al., 2018). In the 800 million years between the formation of the oceans and the presence of the earliest forms of life, simple organic molecules such as amino acids (Miller, 1953) and/or nucleic acids (Rich, 1962) were formed from the dissolved molecules in Earth's oceans. While this historical evidence is documented in the scientific community, there is relatively little experimental evidence to support a mechanism linking the aggregation of these primitive molecules to form a larger molecule capable of self-replication. In this thesis, I sought to determine a candidate providing the organizing principle capable of aggregating molecules together in aqueous solutions, as was present on early Earth. One such candidate as was hypothesized by Cole and Graf (1974) is Earth's geomagnetic field.

1.1 Magnetic Fields

Electromagnetic fields are ubiquitous in modern urban environments (Knave, 2001). Electromagnetism is a phenomenon that occurs in matter due to the movement of electrons. The electric component of an electromagnetic field refers to the flow of electrically charged particles while the magnetic portion is denoted by flux lines of energy involved in the attraction of opposing charges or the repulsion of identical ones. An electromagnetic field, by definition, is the production of a force resulting from the movement of these electrically charged particles (Fahidy, 2002) which is expressed by the mathematical expression $F = qv \times B$, where F represents the Lorentz force, qv is the velocity of the fundamental charges in motion, and B is the strength of the electromagnetic field (Walker, 2004). Electromagnetic fields can be classified as an alternating field, containing fluctuations in both intensity and frequency, or they as a static field, where the intensity of the field remains constant. In other words, a static magnetic field has no frequency (0 Hz), while an alternating field can be propagated at a wide range of frequencies. In this dissertation, the effects of static magnetic fields will be discussed.

A magnetic field is said to be composed of flux lines, imaginary lines of force that travel between the south pole of a magnet and the north pole. The intensity of a magnetic field is the result of the number of flux lines in a given space. This intensity is proportional to the density of flux lines, meaning magnetic fields will have a greater intensity when there are more flux lines present in space. Although the intensity of a static magnetic field is relatively constant, it does undergo a slow decay over time due to increasing disorder and entropy. The strength of a magnetic field is measured in Tesla (T). Common magnets that are able to produce a static magnetic field include "fridge magnets" which normally have a magnetic field strength of 5 mT. A typical magnetic resonance imaging device (MRI) employs a magnet that can generate a static field in the range of 1 T – 7 T. The Earth also produces its own magnetic field with a strength ranging from 30 μT – 70 μT which has been present since the Earth's formation (Cole and Graf, 1974). In other words, a fridge magnet produces a local magnetic field that is ten thousand times stronger than that detected from the Earth.

Static magnetic fields are capable of affecting matter at a distance. They may affect a biological system by influencing the orientation of biomolecules which are composed of an uneven distribution of charges. As an example, liquid oxygen (O_2) is considered to be paramagnetic when it is exposed to an externally applied magnetic field since it is an element which contains two unpaired electrons, meaning it has two partially filled electron shells. The unpaired electrons are able to align themselves parallel to the field, causing them to be attracted to that field. In paramagnetic compounds, the unpaired electrons, or dipoles, are present prior to exposure to a magnetic field and do not retain any magnetism after the removal of the field. In contrast, matter is said to be diamagnetic, or repelled by a magnetic field, when all of the electron shells are filled. A typical fridge magnet is considered ferromagnetic, one descriptor used to describe a permanent magnet. These materials are permanently magnetized even in the absence of a magnetic field.

Magnetic fields can also penetrate living tissue, or aggregates of cells. The time required for magnetic fields to induce their effects is dependent upon the electrical properties of the medium it is affecting which can influence the resistance, capacitance, and inductance of the field (Geddes and Baker, 1967; Gabriel et al., 1996). The rationale behind the idea that magnetic fields can act as an ongoing principle with the synthesis of larger molecular aggregates that form organisms is that all life forms are composed of the fundamental elements carbon, hydrogen, oxygen and nitrogen which combine to form molecules with dipoles (Woodard & White, 1986). Every chemical element is associated with an electric charge, as subatomic particles that comprise elemental atoms are also charged protons (positive), electrons (negative) and neutrons (no charge) (Parr, Ayers, & Nalewajski, 2005). Noble gases, such as Argon, do not have an electric charge. Static magnetic fields are thought to be capable of shifting the orientation of electrically polarized cells (Rosen, 2003) thus causing an alteration in the structure of a tissue.

1.2 The Properties of Water

Water has been present on Earth almost from the beginning 4.6 billion years ago. Biologists have come to the consensus that life on Earth originated in the water held within its oceans. (Stillinger, 1980). Water is a tasteless, odorless, and transparent compound resulting from the combination of hydrogen and oxygen, two of the most common elements in the known Universe. Water is capable of existing in multiple different physical states. It is most abundant on Earth in its liquid state, but it is also present as a solid (ice) and a gas (water vapor). This water is said to be the “solvent of life” since many biochemical processes and metabolic pathways important for sustaining life can only occur in this medium. It is also often designated as the universal solvent due to its ability to solvate many other substances.

Despite its chemical simplicity, individual water molecules are capable of interacting in higher order structures to produce clusters ranging in size and shape, making it very complex to understand. These higher order clusters of water exist very briefly since the ions present in the clusters jump between molecules with a lifetime of 1 picosecond (Geissler et al., 2001) and a mobility of 3.6 x 10^{-3} $cm^2/V \cdot s$ (Eigen and De Maeyer, 1958). The ability of water to form clusters is in large part due to the ability to form hydrogen bonds between molecules, a type of intermolecular force between polar molecules, caused when the hydrogen atom with a partially positive charge interacts with the oxygen atom of a separate molecule with a partially negative charge. In addition, protons can be passed from one water molecule to the next, transiently creating hydronium ions. It was demonstrated by Wernet et al. (2004) that a water molecule in its liquid state can make and accept one hydrogen bond, forming chains or rings as opposed to previously hypothesized tetrahedral networks. This study complemented the experiments conducted by Narten and Levy (1969) which revealed that two to three water molecules formed a non-random arrangement around a central molecule. Chang and Weng's experiments (2006) demonstrated a small increase of 0.34% in the number of hydrogen bonds present in water exposed to a magnetic field when the magnetic field strength increased from 1 T to 10 T. Hosoda et al. (2004) suggested that this was due to an increase in electron delocalization occurring among the hydrogen-bonded molecules.

Other sources of energy are capable of affecting the structure of liquid water molecules. Liquid water can change between different states when certain temperature thresholds have been achieved. The most obvious observations of this phenomenon include; 1) the solidification of water to ice by decreasing the water's temperature, and 2) the evaporation of water into a gas phase by increasing its temperature. In the first instance, the freezing of water causes the molecules inside to slow down, bringing them closer together. However, because water molecules are capable of forming hydrogen bonds, there is an increase in the formation of these bonds when the temperature decreases, creating spaces between the molecules. This concept explains why water expands when ice is formed and the density of ice is less than for liquid water. In the latter case, when water evaporates, the molecules move and vibrate faster, creating a greater distance between them, thus limiting the formation of hydrogen bonds. The properties of liquid water can be affected even when it does not involve a change n physical states. According to Marcus (2009), some properties of liquid water can be influenced by an increase in temperature. These properties include; 1) the "stiffness", or amount of work required to create a cavity in the liquid, 2) the “order”, or the ability for water molecules to remain cohesive, 3) heat capacity, or the amount of energy needed to increase the water’s temperature, and 4) the extent to which water molecules form hydrogen bonds. He demonstrated that the aforementioned properties of water structure were inversely proportional to temperature. He also demonstrated that the addition of certain ions can either enhance or diminish hydrogen bonding and water structure.

Water is a complicated substance. When it is exposed to different environmental stimuli such as light, its properties, and hence its complexity, can change depending on the stimulus. One such state is the formation and expansion of the exclusion zone (EZ) by light as described by Gerald Pollack in his book, *The Fourth Phase of Water* (Pollack, 2013). He highlights that EZ water is situated at an interface with a hydrophilic surface, and is capable of excluding molecular solutes. Prominent features of EZ water include: a 10-fold increase in viscosity compared to bulk water, peak light absorption at 270 nm, and a negative electric potential allowing it to act as a battery, whereas bulk water is positively charged (Pollack et al., 2009). This state may seem relevant to life since a cell is composed of a plasma membrane, an interface with a hydrophilic surface surrounded by water.

Persinger (2015) recently reviewed another important feature of water known as thixotropy. This exceptional property emerges from liquids and gels whose viscosity slowly increases in relation to the fundamental ordering of large numbers of water molecules. According to Persinger (2015), the viscosity of water at 25°C is 8.94×10^{-4} $kg \cdot m^{-1} \cdot s^{-1}$. Vybiral and Voracek (2007) determined that undisturbed water containing ions developed a gel-like behavior spontaneously, and that this effect was dissipated with the introduction of mechanical stimuli. It is suspected by Verdel et al. (2011) that thixotropy occurs in water via proton transfer involving Grothuss-like mechanisms within the structured networks of hydrogen bonds between water molecule. Del Giudice and Preparata (1994) predicted that weak magnetic fields could be contained within water molecules in this state.

Karbowski and Persinger (2015) stated that water possesses some of the basic properties of universal particles. By taking the ratio of the magnetic moment of a proton (1.41×10^{-26} $A \cdot m^2$) and the standard unit charge (1.6×10^{-19} $A \cdot s$), a diffusivity value emerges equaling 8.8×10^{-6} $m^2 \cdot s^{-1}$. Multiplying this value by the viscosity of water at 25°C (8.94×10^{-4} $kg \cdot m^{-1} \cdot s^{-1}$) yields a force of 7.87×10^{-11} kg·m·s^{-2}. Dividing this value by the distance across two O-H bonds (1.92×10^{-10} m) produces an energy value equivalent to 1.5×10^{-20} J, a very important molecular quantum associated with a variety of biomolecular pathways such as the amount of energy released during an action potential (Persinger, 2010). This value also correlates within error measurement of the second shell hydrogen bonds that have been revealed to contribute to the mobility of protons in water (Decoursey, 2003).

1.3 Effects of Static Magnetic Fields on Aqueous and Biological Systems

There is an increasing amount of evidence supporting the notion that static magnetic fields are capable of affecting water. Magnetic fields that are much stronger than the one generated by the Earth's molten core which produces a magnetic field with an intensity ranging from 25 μT to 65 μT can be used. As previously stated, Chang and Weng (2006) demonstrated that increasing the magnetic field strength from 1 T to 10 T also increased the number of hydrogen bonds in water by 0.34%. Hosoda et al. (2004) suggested that this increase in hydrogen bonds is due to an increase in electron delocalization occurring in the hydrogen-bonded molecules.

In the case of flowing water, Coey and Cass (2000) passed ground water drawn from a well through a static magnetic field with a maximum field intensity of 0.1 T. They reported that water treated with a magnetic field favored the formation of aragonite crystals as opposed to calcite crystals (this was after heating the water). Both of these crystals have the chemical formula $CaCO_3$, but their atoms are stacked differently, meaning the molecular structure is different. Gang and Persinger (2011) revealed that hydrostatic water displayed a change in viscosity following a one hour exposure to a magnet producing a static magnetic field with an intensity of 1.6×10^{-1} T. This effect was dependent on the intensity of the magnetic field which was modified by manipulating the distance separating the magnet from the water. The viscosity of water displayed its greatest increase when the magnetic field intensity was at its maximum intensity which decreased the mobility of planaria. Ghauri and Ansari (2006) performed an experiment where they confirmed an increase in the viscosity of water subsequent to an exposure to a powerful static magnetic field with an intensity comparable to that used in Gang and Persinger’s experiment. They hypothesized that the magnetic field increased the amount of hydrogen bonds which corroborates Chang and Weng’s (2006) findings.

Nakagawa et al. (1999) revealed that exposure to strong static magnetic fields up to 8 T showed an enhancement in the rate of water vaporization. Pang and Deng's multiple experiments (2007, 2008) demonstrated changes in the organization of water molecules, but not in the constitution of water, following a 15 minute exposure to a static magnetic field with an intensity of 4.4×10^{-1} T. These observations are supported by Toledo et al. (2008) who validated increases in water vaporization, surface tension, and viscosity when water was exposed to a static magnetic field. Increases in networks of hydrogen-bonded water molecules appear to be the common rationale among all of the experiments of this nature.

Since all living organisms rely on water to survive, it is rational to assume that affecting water in some way may also affect the living organisms that consume it or use it as a form of habitation. For example, Morejón et al. (2007) assessed the germination process of the *Pinus tropicalis* M. seeds that were treated with water that had been previously exposed for 48 hours to a static magnetic field possessing a field strength of 1.2×10^{-1} T. They demonstrated that a larger portion of seeds germinated from the groups that were irrigated with the magnetically treated water (~80% germination) compared to control groups (~40% germination). They attributed this increase in germination to the changes in the physical and chemical properties of water following magnetic field exposure. Gang and Persinger (2011) evaluated the mobility of a living organism, the planarian flatworm, in spring water that had been previously exposed to a static magnetic field of 1.6×10^{-1} T in intensity. It was highlighted that the planarian velocity significantly decreased as a function of the intensity of the magnetic field used to treat the water. They argued that the increase in the viscosity of water subjected to a magnetic field may be responsible for the decrease in planarian mobility. In both instances, the effects observed were correlated to the magnetically treated water.

1.4 The Present Study

The current dissertation aims to elucidate the effects that exposure to a strong static magnetic field have on solutions of water and how a magnetic field may, in turn, influence the organic and inorganic matter within it. The previous literature has demonstrated that the structure of water can be easily influenced with various stimuli. If the higher order structure of water can be changed, then perhaps the matter housed within it can also be changed. Here, the effects of exposure to a strong static magnetic field on water was investigated by; 1) exposing spring water containing ions and minerals to a powerful static magnet in the dark for a 5 days in order to test for any observable effects, 2) exposing spring water to a different type of energy (heat) to see if there is a difference from magnetic field exposure, 3) exposing solutions of cell culture media to a powerful static magnet in the dark for 24 hours and then evaluating the cell’s ability to multiply in this new environment.

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Chapter 2 – Magnetically Mediated Crystal Formation in Spring Water: Understanding the Fundamentals of Abiogenesis

2.1 Abstract

The response of spring water exposed to a strong static magnetic field in the absence of any light was examined. Individual solutions of spring water were placed inside a dark box and exposed to either a sham field or a Raytheon horseshoe magnet with a strong static magnetic field (0.16T) for 5 days. An aggregated crystalline network formed at the surface of the spring water following the experiment. It was determined that solutions of spring water exposed to the magnet produced a significantly larger amount of crystals than water exposed to the sham field condition. The amount of crystals produced was proportional to the volume of spring water. Spring water exposed to heat conditions also displayed crystals although these crystals were significantly different in shape and structure. Studies suggest that these results could be due to the magnetization of water. These results support the notion that magnetic fields can increase the rate of aggregation of matter present in water which may serve to expand the literature on the theory of abiogenesis.

2.2 Introduction

Research has shown that water can be partially aligned with an electrostatic force (Bramwell, 1999). This, in turn, causes configurational changes between water molecules and the networks they form. More specifically, it bends and breaks hydrogen bonds in an anisotropic manner. The bonds that are parallel to the field are strengthened whereas those that are orthogonal to the field are weakened (Vegiri, 2004). One study showed that water molecules would orient towards an electrode possessing a potential of -0.23 V, and that this could be reversed by introducing an electrode with a potential of +0.52 V (Michot et al., 2002). The electric field is capable of orienting water molecules by breaking and reforming hydrogen bonds. Water can also respond to magnetic fields. Simulations have shown that water molecules exposed to magnetic fields at an intensity similar to the Horseshoe Magnet (0.16 T) display an increased number of monomer water molecules and tetrahedral-organized water is also enhanced (Zhou et al., 2000). An increase in the refractive index of water exposed to magnetic fields has been attributed to an increase in hydrogen bonding which may also be why there is an increase in the ordered structure of water formed around hydrophobic molecules. One study suggests that magnetic fields are capable of increasing the proton spin relaxation, thus facilitating reactions that require proton transfer (Madsen, 2004). Ultimately, magnetic fields produce structural effects on water. Taken altogether, electric fields should be able to increase the reactivity of substances in water due to the decrease in structured water and hydrogen bonding. On the other hand, magnetic fields favor hydrogen bonding and structured water, thus reducing the participation of water molecules in reactions.

The structure of a single water molecule is relatively simple; one oxygen atom bonded to two hydrogen atoms at an angle of approximately 106°. However, aggregates of water molecules can form a multitude of various coherent networks via very weak bonds that can rapidly change (on the order of a microsecond). These structural networks are known as Coherence Domains which can span a distance over 0.1 µm, include millions of molecules and are highly nano-heterogeneous (Del Guidice et al., 2010). Coherence Domains are said to be clusters of ordered water molecules formed by "trapping" coherent electromagnetic field within it. This allows for Coherence Domains to oscillate, in phase, between the ground state and the excited state (Del Giudice and Preparata, 1995) as well as between two rotational levels, meaning they are capable of rotation (Ho, 2014). In turn, the "trapped" coherent electromagnetic field inside the

Coherence Domain can exert its influence on nearby charged or electrically polarizable molecules. The Coherence Domains in water can possess different structural and functional properties based on the electromagnetic vector potential, **A**, trapped inside. The Coherence Domains are then capable of influencing other Coherence Domains based upon the properties of the electromagnetic vector potential trapped. One can then appreciate the complexity of water structures.

The purpose of this study was determine if a strong magnetic field could affect the solvation of ions present in undisturbed water in the absence of any other outside influences such as alterations in temperature, light, mechanical vibration, to name a few. However, in control experiments changes in temperature was used as another source of energy for comparison to the magnetic field condition.

2.3 Methods

The experiment was initiated by placing 500 mL of spring water inside a clean Erlenmeyer flask sealed with aluminum foil to prevent the introduction of contaminants. The spring water contained concentrations of the following dissolved minerals in parts per million (ppm): As 0, HCO_3 270, Ca 71, Cl 2.7, Cu 0, F 0, Mg 25, NO_3 2.6, Pb 0, K 0.7, Na 1, SO_4 5.9, and Zn 0. The flask of water was subsequently placed inside a black wooden box alongside a Raytheon Horseshoe magnet with a magnetic field strength of ~0.16 T. The small opening to the inside of the box when the lid was closed, was covered with a black towel to prevent any light from penetrating inside. The covered box was left untouched in a darkened room for 5 days to prevent any mechanical disturbances. Two controls were included in this experiment. Distilled water was used to control for dissolved ions and minerals. The second control involved removing the magnet from the box.

Once the 5 days had elapsed, the contents within the flask were filtered using pre-weighed filter paper (Whatman, 90 mm **Ø**, Cat No 1001 090). This filter paper was then isolated in a closed drawer and left to dry for 24 hours. Quantitative measures of total crystal mass were taken by subtracting the weight of the filter paper pre-filtration from the weight of that same paper post-filtration. These values were then transcribed into SPSS for statistical analysis. This procedure was repeated with other volumes of spring water (50 mL, 100 mL, 250 mL). This experiment was repeated 5 times for each condition.

A temperature condition was also included as another form of applied energy to compare with the magnetic field conditions. A clean Erlenmeyer flask containing 500mL of spring water was sealed with aluminum foil to prevent the introduction of contaminants. The flask was then placed on a hot plate until there was a change in the water’s appearance (moments after boiling point was achieved). Afterwards, the crystal precipitates within these solutions of spring water were filtered using pre-weighed filter paper (Whatman, 90 mm **Ø**, Cat No 1001 090) and placed in a closed drawer to dry for 24 hours. The crystals were then observed using an Olympus microscope.

Pictures of crystals for each condition were taken using an Olympus microscope fixed with an Infinity camera attached to it. Image J software was utilized to compute the length/width ratio for the crystals found in both exposure conditions at 1000x magnification. This step served to quantify and assess the possibility of a structural difference in shape between crystals from each condition.

2.4 Results

Crystal Weight

Initial visual observation of the water after being exposed to the static magnet for 5 days in the dark revealed an unexpected white/clear crystal substance floating at the water’s surface. This substance was not present at the beginning of each experiment, nor was it present in the distilled water condition at any point of the experiment. These crystals appear to have aggregated together, forming a coascervate which can be viewed in figure 1 below.

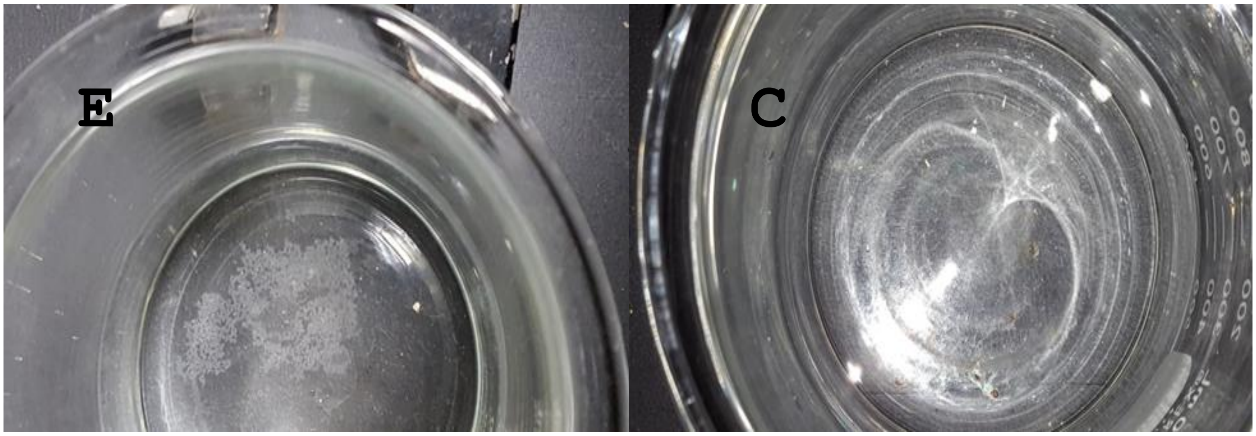

Figure 1. Crystal production effect in spring water after being exposed to a powerful Raytheon Horseshoe magnet (0.16 T) for 5 days. "C" represents the control no magnet group where few to no crystals appeared after 5 days. "E" denotes the experimental group containing a visible aggregate of crystals when the spring water was exposed to the strong static magnet.

On average, solutions of spring water exposed to the Raytheon Horseshoe magnet (16.26 ± 1.10mg, n=5) contained a greater mass of crystals at the water's surface than the solutions exposed to a sham field (1.90 ± 0.759mg). Oneway analysis of variance revealed that this difference was significant [$F(1,8) = 114.142$, $p<.001$, $\omega^2 = .934$]. The results of these measurements can be viewed in figure 2 below.

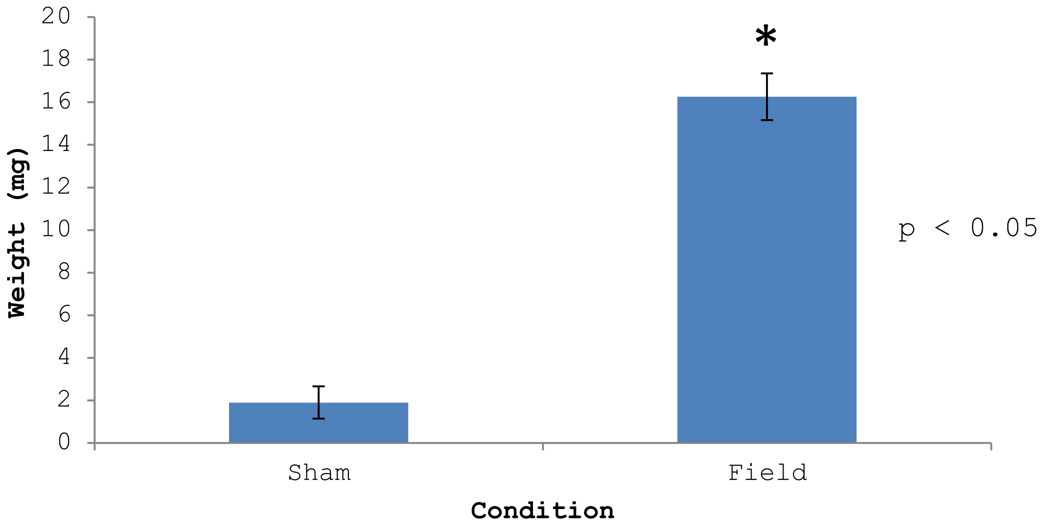

Figure 2 – The average total crystal weight in spring water following exposure to a magnetic field or sham condition for 5 days in the dark, undisturbed. Error bars represent standard error of the mean (n=5).

Statistical analyses were also conducted in order to compare the effects induced in the different volumes of spring water. Kolmogorov-Smirnov's test of normality deemed that all groups were normally distributed. Levene's statistic indicated that the homogeneity of variance between groups was not significantly different. Oneway analysis of variances demonstrated that there was a significant difference in the crystals weight depending on the different volumes of spring water exposed to the static magnet. Application of Tukey's *post hoc* test revealed that the amount of crystals produced in 50mL of water (2.86 ± 0.437mg, n=5) was significantly different from the amount produced in 250mL (6.48 ± 0.739mg) and the amount produced in 500mL (16.26 ± 1.11mg), but it was not significantly different from the amount produced in 100mL (4.44 ± 0.634mg). The results of this statistical analysis can be viewed in figure 3 below.

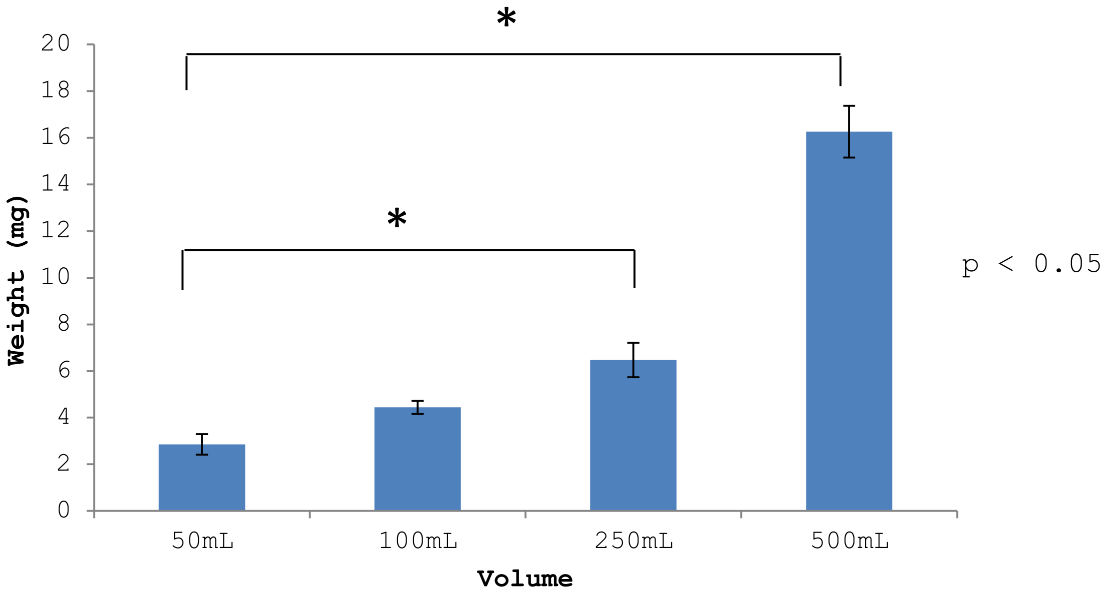

Figure 3 – Average total weight of crystals produced in different volumes of undisturbed spring water following exposure to a static magnetic field (0.16 T) for 5 days in the dark. Error bars represent standard error of the mean (n=5).

Magnetic Field vs. Heat

Statistical analyses were conducted to compare the length/width ratio of crystals found after exposure to the magnetic field and heat conditions. A Kolmogorov-Smirnov's test of normality deemed both groups to be normally distributed. Levene’s statistic indicated that the homogeneity of variance between groups was significantly different and therefore caution should be taken when reporting the results. A oneway analysis of variance demonstrated that there was a significant difference between the length/width ratio of crystals produced in the magnetic field condition and those produced in the heat condition [$F(1,10) = 257,447$, $p<.001$, $\omega^2 = .963$]. On average, crystals produced in the magnetic field exposure condition (1.03 ± 0.0669) displayed significantly smaller length/width ratio values than crystals produced in the heat exposure condition (14.38 ± 0.830). Figure 4 below depicts images taken of dried crystals produced from both conditions. Figure 5 illustrates the results of this analysis.

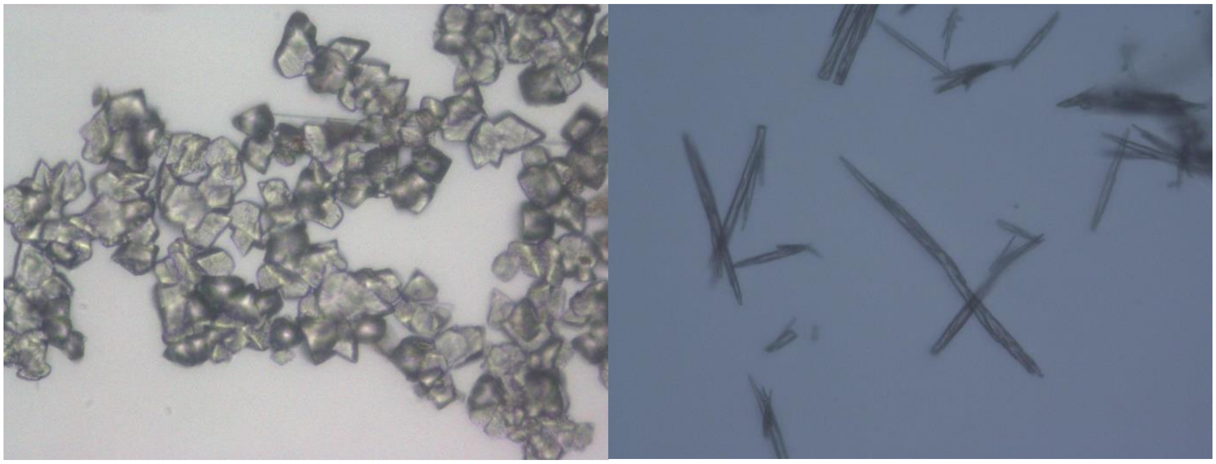

Figure 4. Shapes of crystals in spring water after being exposed to a static magnetic field (left) or a hot plate (right). These images were taken under a microscope at 400x magnification.

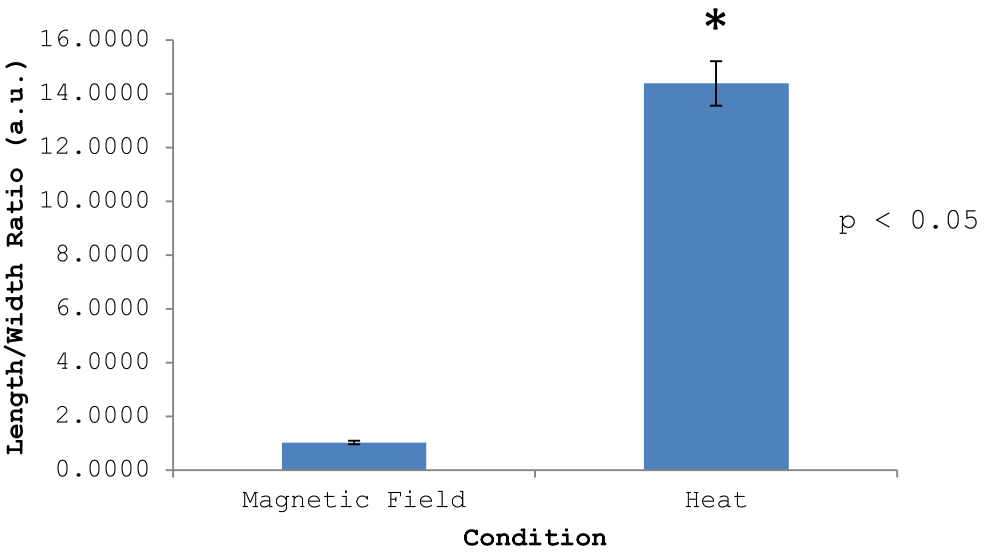

Figure 5. Average length/width ratio of crystals produced in spring water subsequent to an exposure to a static magnetic field (0.16 T) in the dark for 5 days and those produced when the water was placed and heated on a hot plate. Error bars represent standard error of the mean (n=6).

2.5 Discussion

The appearance of a transparent crystal structure at the water's surface was unexpected. The data suggests that there is a greater quantity of crystals produced in spring water when this solvent is exposed to a strong static magnetic field as compared to the no-magnet controls. However, crystals were also generated in spring water even in the absence of exposure to the Raytheon Horseshoe magnet. This implies that the magnetic field was not necessary to produce these crystals, rather that the exposure accelerated the process. Various studies indicate that a magnetic field is capable of magnetizing water by affecting the hydrogen bonding network (Ghauri and Ansari, 2006). Magnetized water has an increase in viscosity, making the liquid thicker, which may help coascervate the molecules inside. According to Persinger (2015), the amount of energy required to maintain a hydrogen bond is on the order of 1.9×10^{-20}J. Using the classical equation $E = B^2/2\mu \times V$, we can easily determine the amount of energy that is being stored in a given volume of water in response to the exposure to a magnetic field. Given that the magnetic field intensity of the Raytheon Horseshoe magnet was 0.16 T and the volume of water was $5.0\text{x}10^{-4}$ m^3 (500mL), the equivalent amount of energy stored in the water is equal to 5.69 J. Since the experiment's duration is 5 days ($4.32\text{x}10^5$ seconds), we can multiply this amount by the amount of energy stored in water to determine the total amount of energy being stored throughout the duration of the experiment, which is equivalent to $2.46\text{x}10^6$ J. To take this calculation one step further, the total number of molecules of water in the experiment must be considered. Given that 500mL of water was used, and that there is 55.5mol/L of water, the experiment was performed on ~27.8mol of water. Multiplying this value by Avogadro's number yields a value of 1.67×10^{25} molecules of water in the exposure vessel. We can now determine how much energy is associated with each molecule of water during the magnetic field exposure. This can be achieved by dividing the total amount of energy from the magnetic field by the number of molecules of water. This division yields a value of 1.47×10^{-19} J/molecule, well within the range of energy associated with reinforcing hydrogen bonding between water molecules. This calculation could validate the hypothesis that the aggregation of crystals in water is due to an increase in viscosity, and by extension, the ordered structure of the solvent of life.

Electromagnetic fields are also capable of generating clusters of ordered water molecules known as Coherence Domains formed by "trapping" coherent electromagnetic fields within it. Energy is required to form a Coherence Domain. Knowing that the amount of energy per water molecule is $\sim 1.5 \times 10^{-20}$ J (Karbowski and Persinger, 2015), we can calculate the approximate amount of energy stored in a Coherence Domain by determining how many water molecules are present in this ordered structure of water and multiplying this number by the aforementioned value. The molar mass of water is 18.02 g/mol. Since the density of water is approximately 1 g/mL, we can alternatively state that the molar mass of water is 18.02 mL/mol. We can determine the amount of moles in 1 L (1000mL) of water by determining the quotient of this value and the molar mass which would equate to 55.5 moles of water. Subsequently, we can calculate the number of molecules in 55.5 moles of water by multiplying this value with Avogadro's number (6.022×10^{23} molecules/mol), yielding a total of 3.34×10^{25} molecules of water. Thus far, we have determined how many molecules of water are present in 1 L of water (3.34×10^{25} molecules/L). With this value, we can calculate the volume of 1 molecule of water using the following mathematical relationship:

$$\frac{3.34 \times 10^{25}\, molecules\ of\ H2O}{1\, L} = \frac{1\, molecule\ of\ H2O}{x\, L}$$

We obtain a value of 3.0×10^{-26} L by solving for the value of one water molecule. Knowing there is 1.0×10^{-3} m^3 in 1 L, we can state that the volume of a single water molecule is roughly 3.0×10^{-29} m^3.

The average size of a Coherence Domain is 0.1 µm (1.0×10^{-7} m) (Del Giudice et al., 2010). Assuming the Coherence Domain has the shape of a cube, its corresponding volume would be 1.0×10^{-21} m^3. We can calculate how many water molecules are present in a Coherence Domain by dividing the volume of the domain with the volume of a water molecule. The quotient of these two values yields a total of ~3.33 x 10^7 molecules. Since the amount of energy per water molecule is ~1.5 x 10^{-20} J, the total amount of energy stored in one Coherence Domain just from water is approximately 5.0 x 10^{-13} J, or half a picoJoule. This calculation indicates that there is a sufficient amount of energy within a Coherence Domain to maintain multiple hydrogen bonds. A key feature about Coherence Domains is that they are formed in response to exposure to electromagnetic fields. Earth has had its own geomagnetic field since its beginning roughly 4.6 billion years ago. The Earth's geomagnetic field is constantly fluctuating due to the impact of solar wind. This has an interesting implication for the formation of Coherence Domains that are present in interfacial water within the space of the geomagnetic field. The influence of a fluctuating geomagnetic field generates varying Coherence Domains, which can differ in size, structure, composition, and oscillation. Different networks of hydrogen-bonding water molecules with their unique properties could then influence surrounding molecules that resonate at similar frequencies, capturing these molecules expanding the networks. As the Coherence Domain fluctuates and rotates, the energy transfer occurring between adjacent Coherence Domains via proton and electron sharing could induce further configurational changes in the surrounding water networks and in the surrounding dissolved molecules. This idea might also explain the mechanism by which amino acids or ribonucleotides aggregate together, using the energy within their Coherence Domains, to form linear complexes that can subsequently be covalently linked to form polymers such as proteins and ribonucleic acids, respectively. Considering that the Earth's volume of water is approximately 1.38×10^{18} m^3 and each Coherence Domain is roughly 1×10^{-21} m^3 (assuming it is a cube with an average length of 100 nm), the quotient of the two would equate to approximately 1.38×10^{39} defining the upper limit for the number of Coherence Domains which could exist. That leaves room for countless possibilities and different configurations within each Coherence Domain.

In this experiment, the crystals generated by exposure to sham or static magnetic fields are thought to be largely composed of calcium carbonate ($CaCO_3$) (Pearson, 1985). This was validated using the qualitative flame test, whereby the dried crystals projected a flame with an orange hue consistent with the presence of $CaCO_3$. According to Madsen (1995), the crystallization reaction that occurred in spring water under the influence of a magnetic field is: $Ca^{2+} + HCO_3^- + H_2O \rightarrow CaCO_3 + H_3O^+$. Madsen (1995) argues that the reaction primarily involves the transfer of a proton from a weak acid (HCO_3^-) to water. He suggests that the rate of proton transfer was doubled in aqueous solutions containing carbonate molecules that were exposed to a powerful static magnetic field because the field can affect the orientation of the proton spin on the carbonate molecule. This concept may also provide a link to the increased viscosity of water when exposed to a static magnetic field.

One commonly used measure to detect the quantity of a compound of a solute in solution is parts per million, or ppm. As the name suggests, ppm represents the parts of a solute present for every 1 million parts of the solution. This unit is typically employed when calculating extremely low concentrations of contaminants independent of their molecular weight. Nevertheless, this expression is very useful for determining the quantities of a solute in any solution. The mathematical representation of ppm is 1 mg of solute per 1 L of an aqueous solution, or 0.001 g / 1000 mL. The spring water that was used in this experiment has been tested for various components and is labelled to show the level of different ions that are dissolved in solution in ppm. For example, the presence of the calcium ion, which appears to be the main component of the crystal structures formed in this experiment is shown to be present at 71 ppm in the water. Knowing this, we can determine the average mass of calcium ions present in the volume of water used in experimental set up. The initial experiment consisted of exposing 500 mL of spring water to a powerful static magnet for 5 days in the dark. Since 1 ppm is equivalent to 0.001 g / 1000 mL, and the spring water contains 71 ppm of calcium, or 0.071 g / 1000 mL, each 500 mL aliquot corresponds to a mass equivalent of 0.0355 g or the maximum amount of calcium present in each experiment. Our experiment showed that the average amount of crystals produced in the spring water exposed to the powerful static magnet for 5 days was 16.26 mg or 0.01626 g. The percentage yield can be determined by dividing this number by the total amount of calcium in each experiment (0.0355 g) and multiplying this value by 100%. In this experiment, exposure to the static magnetic field resulted in 45.8% of the calcium being present in crystals.

Of particular interest, the morphology of these crystals was similar to aggregated filaments that were oriented in such a way as to form a network. Microscopy confirmed the vast complexity of this network of crystalline structure. The visual appearance of the crystals formed in response to exposure to the magnetic field was quite different from those generated by exposure to heat. The average width/length ratio of crystals produced in heating conditions is far greater than those produced within a magnetic field setting. This indicated that there is a difference in crystal shape between the two conditions. The crystals produced under the influence of a magnetic field look to be ordered and inter-connected whereas those generated by exposure to a heat source appear to be irregular and cuboidal. This suggests that exposure to different types of energy can produce remarkably different effects on the same aqueous system. Kainuma et al. (2006) demonstrated that a magnetic field was capable of inducing near full recovery of the shape of metal alloys that had already been deformed. These results suggest that a magnetic field may play a prominent role in the in binding and maintaining the structure of aggregated molecules in water.

Taken altogether, this evidence suggests several possibilities. Firstly, it suggests that a strong magnetic field may be able to catalyze chemical reactions in an aqueous medium, resulting in this case to the formation a precipitated product. Furthermore, it may indicate the capability of a magnetic field to promote the formation of aggregates of dispersed matter in aqueous solutions. Additionally, these results suggest that magnetic fields may be capable of increasing the rate of aggregation to enhance the nucleation of crystals in spring water. Conversely, it also appears that crystal shape and connectivity are affected by the specific nature of the energy used in the exposure. Lastly, this could help explain how Earth’s magnetic field was able to contribute to the formation of polymers of biomolecules as suggested in the theory of abiogenesis stipulated by Cole and Graf (1974), albeit over a far greater span of time than was demonstrated in this experiment.

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Chapter 3 – Mathematical Exploration Supporting the Historical Convergence of Eukaryotic Cell Formation on Earth Using Geomagnetic Energy

3.1 Abstract

Cole and Graf (1974) hypothesized that Earth's electromagnetic field contributed to the phenomenon known as abiogenesis. They suggested that the geomagnetic field was involved in the alignment, binding, and polymerization of amino acids and/or nucleic acids found in Earth's primordial oceans to form larger molecules capable of self-replication. In support of this case, a series of mathematical calculations to determine the impact of the geomagnetic field on the rate of bond formation required to construct a cell was determined. The human cell was broken down into the approximate number of bonds required to construct it. Subsequently, the flux density of the geomagnetic field was calculated and utilized to determine the approximate theoretical length of time that would be necessary to form all of the bonds one human cell using geomagnetic energy. This set of calculations may prove to be useful in determining the total amount of time that was required to produce the earliest organisms on Earth should the mechanism of their abiogenesis involve the geomagnetic field.

3.2 Introduction

Cole and Graf (1974) have suggested a theoretical mechanism that may shed light on the mechanisms of abiogenesis. They suggested that the primitive Earth’s geomagnetic field, present since Earth’s inception and generated by convection of the molten core, may have been responsible for providing the appropriate alignment required to facilitate the organization of the newly synthesized amino acids within Earth’s seas to facilitate their polymerization into proteins. It may have also been responsible for providing stereochemical selection of these molecules with the selection of particular stereoisomers for building larger polymers. For example, proteins are exclusively composed of L-amino acids. The geomagnetic field possesses both a static component as well as a time-varying component, and each of these components are subdivided into an electric field and a magnetic field. The static electric field (E_s) and the static magnetic field (H_s) vectors of the geomagnetic field are operating in a parallel direction, whereas the time-varying sinusoidal electric (E_t) and magnetic (H_t) field vectors act perpendicular to the static fields. The static electric field also has a much greater magnitude than the sinusoidal electric field. In this particular instance, the negative end of an amino acid would be expected to align with the positive charge of the static fields. More specifically, the terminal carboxyl group of the amino acid would have a negative charge and therefore would be facing upwards towards the water’s surface since the Earth’s oceans were alkaline (pH ~ 8) under the influence of the geomagnetic field. Subsequently, the alternating fields would preferentially select the amino acids with an L conformation to align at the water’s interface. This would promote the optimal spatial conformation for the amino acids to form polypeptides in a top-down fashion. Similarly, nucleic acid polymers such as RNA and DNA could be organized at interfacial water under the influence of geomagnetic fields. One theory suggests that RNA may be the critical molecule involved in the abiogenesis of living systems since it has the capacity to self-replicate in a conserved fashion allowing propagation of a evolutionary selectable network. From there, these molecules would continue to evolve until the emergence of the very first cell. This process would have taken a large amount of time, and it may be possible to estimate this value given what is currently known about the geomagnetic field and the molecular structure of a cell. The purpose of this experiment was to estimate the amount of time required for abiogenesis by exploring the fundamental unit that composes all living organisms on the planet: the cell. More specifically, the human cell was examined. In addition, this information may be useful in approximating the amount of time required to produce a single typical cell under the influence of geomagnetic energy.

3.3 Number of Bonds Forming a Human Cell

A human cell is composed of many important structures that ensure its functionality and sustainability. To begin, a single human cell weighs approximately 3.5 x 10^{-9} g on average (Lodish et al., 2000). Approximately 90% of a human cell's weight is attributed to water (70%) and protein (20%). Knowing the molecular structure of water and the general molecular structure of amino acids (which compose proteins), we can discern how many bonds are required to form roughly 90% of a human cell. From there, it is possible to calculate an interval of time to synthesize the major molecules that make up a cell using geomagnetic energy. Calculations involving the properties of water in the cell will be considered first.

It is interesting to note that the majority of the cell is composed of water. The prevailing hypothesis stipulates that life originated in Earth's oceans, and this water has been present very shortly after Earth's inception. Roughly 70% of a human cell's weight, or 2.45 x 10^{-9} g, is water (Lodish et al., 2000). Using this value, we can determine the number of moles present in the cell using the molar mass of water (18.02 g/mol). The quotient between water's weight in the cell and its molar mass is 1.36 x 10^{-10} mol. We can employ Avogadro's number (6.02 x 10^{23} molecules/mol) to find the number of water molecules inside the cell. Multiplying the number of moles by the number of molecules per mole of water reveals a value of 8.19 x 10^{13} molecules. Finally, each water molecule possesses two O-H bonds. The last calculation involves multiplying the number of molecules of water in the cell by the number of bonds per water molecule to give 1.64 x 10^{14} bonds. This implies that there are 164 trillion bonds present in all of the water present inside of a human cell.

Next, we will consider proteins, the second most abundant component of a cell comprising 20% of a cell's weight (Lodish et al., 2000). The total amount of protein in a single human cell has a mass of 7.0 x 10^{-10} g. We can then convert this mass to a more appropriate molecular scale unit, the Dalton (Da). There are 1.66 x 10^{-24} g in 1 dalton, therefore dividing the protein weight (7.0 x 10^{-10} g/cell) by the conversion factor yields the amount of 4.22 x 10^{14} Da/cell.

Proteins are macromolecules. A protein is composed of a primary chain of molecules known as amino acids which provide the protein with its secondary and tertiary structures. The average weight of a single amino acid is 110 Da. Knowing the total weight of the proteinaceous material in a cell

(4.22×10^{14} Da/cell), we can divide this number by the average weight of a single amino acid (110 Da/amino acid) to determine the total amount of amino acids within it, which is 3.84×10^{12} amino acids/cell. According to Phillips and Milo (2015), the median length of a protein in a human cell is approximately 375 amino acids. Therefore, dividing the total amount of amino acids in a cell by the median length of a protein provides us with a total average amount of proteins in a cell, which is 1.02×10^{10} protein molecules. To put in perspective, there are more proteins in each human cell than there are humans on Earth, which is estimated at roughly 7 billion. Since there are, on average, 10 trillion cells in a human body (1×10^{13}), there would be an average total of 1.02×10^{23} protein molecules in a human body.

To determine the number of bonds present in all of the proteinaceous material in a single human cell, we must consider the structure of the amino acids. The skeleton (NH_2-CHR-COOH), or core structure that is present in each of the 20 amino acids, contains 10 bonds. The R-chain has a minimum of 1 bond (glycine) and a maximum of 23 bonds (tryptophan). By taking the average amount of bonds in the R-chain for all of the amino acids (12 bonds), adding this to the amount of bonds in the skeleton (10 bonds), and multiplying this total value (22 bonds) by the number of amino acids in a cell (3.84×10^{12} amino acids) gives a total average of 8.45×10^{13} bonds per cell, or 84.5 trillion. Adding this value to the 1.64×10^{14} bonds from water indicates that roughly 90% of a human cell is composed of 2.49×10^{14} bonds.

3.4 Flux Density of Geomagnetic Field and Bond Formation

The Earth has been immersed within an electromagnetic field produced by the convection and rotation of its iron core since its formation. We can determine the amount of energy stored within an electromagnetic field using the equation $E = B^2/2\mu \times V$, where E is the amount of energy, B is the intensity of the geomagnetic field measured in Tesla, μ is the magnetic permeability constant ($4\pi \times 10^{-7}$ H/m) and V is the volume of the Earth (1.09×10^{21} m^3). According to Tarduno et al. (2007), the current intensity of the geomagnetic field (5.0×10^{-8} T) is roughly double its historical average. Assuming the lower limit of the Earth’s magnetic field intensity (2.5×10^{-8} T), the amount of energy produced by the Earth’s magnetic field can be calculated to be 5.42×10^{11} J.

Next, we can calculate the flux density, or the flow of energy, that is produced by the Earth’s geomagnetic field. The flux density is the rate of energy per unit time in a given area (denoted by $J/m^2 \cdot s$). Assuming that the Earth’s magnetic field operates at a peak frequency of 7.5 Hz (Hz is denoted by 1/s, or number of cycles per unit time), the multiplication of this value with the amount of energy produced by the electromagnetic field is 4.07 x 10^{12} J/s. Lastly, we divide this value by the surface area of Earth (5.10 x 10^{14} m^2) to determine the flux density of the Earth's magnetic field, which is 7.98 x 10^{-3} $J/m^2 \cdot s$. In other words, the rate of energy produced by the geomagnetic field at a given area on the Earth's surface is 7.98 x 10^{-3} $J/m^2 \cdot s$.

We can also determine the flux density of bond formation, or how many bonds are formed in a given unit of time. According to Persinger (2010), the average amount of energy required for a bond to form is on the order of 1.9 x 10^{-20} J. If we assume that the amount of time it takes to form a bond is equivalent to the amount of time it takes to stack nucleotides (2.0 x 10^{-2} s) (Koren et al., 2015) and that the average width of a covalent bond, assuming the geometry of a cylinder, is equal to 1.5 x 10^{-10} m (Persinger, 2010), the flux density of bond formation is 3.36 x 10^{0} $J/m^2 \cdot s$. The quotient of this value and the calculated flux density for geomagnetic energy provides a number describing the amount of bonds formed per unit time using geomagnetic energy, or 2.37 x 10^{-3} bonds/s.

3.5 Length of Time to Produce Human Cell

Finally, we can determine the total amount of time necessary to produce a single typical human cell using geomagnetic energy simply by dividing the total amount of bonds by the rate of bond formation. The quotient of the total amount of bonds (2.49×10^{14} bonds) and the rate of bond formation (2.37×10^{-3} bonds/s) yields a value of 1.05×10^{17} seconds, or roughly 3.33 billion years. This is assuming each bond is formed in succession and that no errors were committed in the process. This is also assuming no other environmental factors affected the system. One can then appreciate the amount of time it might have taken for the very first life form to appear on this planet. According to Vidal (1984), the earliest eukaryotic cell appears to be at least 1.4 billion years old, although a more recent source indicates a later appearance of 800 million years ago (Cavalier-Smith, 2009). These values suggest that the first eukaryotic cell could only have appeared on Earth between 3.2 – 3.8 billion years after its inception. This set of calculations determined a value within this range, and it may also prove to be useful in determining the total amount of time to produce the earliest organism on Earth should the mechanism of aggregation involve the geomagnetic field.

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Chapter 4 – Pre-emptive Exposure of Cell Medium to Static Magnetic Field Induces Increased Cell Proliferation

4.1 Abstract

The primary focus of this experiment was to evaluate the indirect effect a strong static magnetic field may have on cell growth. Specifically, the media used to culture these cells was pre-emptively exposed to the magnet in the dark before being used to grow the cells. Stacks of 3 small plates containing 2.5mL of media were placed in a sealed Styrofoam box containing a Raytheon Horseshoe magnet. These stacks were positioned at each pole of the magnet for 24 hours. The control group was a stack of plates with media in a separate box without a magnet. The media was then used as the culture support for B16-BL6 mouse melanoma cells for a period of 6 days. Cell counting protocols were followed to assess cell number. The results demonstrated that the media pre-exposed to a strong static magnetic field supported growth of a larger number of cells compared to cells growing in media exposed in the absence of a magnetic field. These results support the notion that subjecting a liquid to a magnetic field a priori will affect the behavior of biological matter.

4.2 Introduction

Exposing living cells to magnetic fields has been a popular field of research albeit with varying results. Understanding the mechanism for the underlying effects produced by magnetic fields on cells may prove to be useful in narrowing their impact on larger systems composed of cells such as tissues (Kotani et al., 2009), tumors (Tofani et al., 2003), and living organisms (Saunders, 2005). However, since there is great variability between the structure of different types of tissues, tumors, and living organisms, it should stand to reason that the responses of these structures to a specific stimulus could be different. This was demonstrated by Tessaro et al. (2015) where different species of bacteria displayed differences in growth rate following their exposure to the same magnetic fields. They attributed this difference to the individual biophysical characteristics of each bacterial species.

A common substance in all living systems is water. Since all living organisms rely on water to survive, it was though that affecting water in some way may also affect the living organisms that consume it or use it as a form of habitat. For example, Morejón et al. (2007) assessed the germination process of *Pinus tropicalis* M. seeds that were treated with water that had been previously exposed for 48 hours to a static magnetic field of 1.2 x 10^{-1} T in intensity. They demonstrated that more seeds germinated in the groups that were treated with magnetically treated water (~80% germination) compared to control groups (~40% germination). They attributed this increase in germination to the changes in the physical and chemical properties of water following magnetic field treatment. Gang and Persinger (2011) evaluated the mobility of a living organism, the planarian flatworm, in spring water that had been previously exposed to a 0.16 T static magnetic field. They showed that the planarian velocity significantly decreased as a function of magnetic field intensity. They argued that an increase in the viscosity of water in response to exposure to a magnetic field may be responsible for the decrease in planarian mobility. In both instances, the effects observed were correlated with the use of the magnetically-treated water.

The purpose of this study was to evaluate the effects of a powerful static magnetic field on solutions of cell culture media in the dark for 24 hours and then evaluating the ability of cell cultures to proliferate once it is introduced in this new environment.

4.3 Methods

B16-BL6 mouse melanoma cells were employed for this study. These cells were cultured in Dulbecco’s Modified Eagle’s Medium

(DMEM) with 10% fetal bovine serum, 100U/ml penicillin G, 100µg/ml streptomycin sulfate and 250ng/ml amphotericin B. They were also maintained in an incubator at 37°C in 5% CO_2 and subcultured 1:5 every 3 to 4 days. To subculture, the single layer of cells was washed with PBS at a pH of 7.4, and collected following incubation in 0.25% trypsin-EDTA. The cells were then collected by centrifugation at 300x g for 10 minutes.

Stacks of 3 small plates containing 2.5mL of media were placed in a sealed Styrofoam box containing a Raytheon Horseshoe magnet (0.16T) to prevent any light from influencing the media. These stacks were positioned at each pole of the magnet for 24 hours. The control group was a stack of plates with media in a separate box without a magnet. The control box was located away from the box containing the magnet. Following the laboratory's cell splitting protocol, roughly 10^6 cells were injected into the plates after the exposure period and then placed in the incubator to allow the cells to grow. They remained in the incubator for 6 days which provided the cells with adequate time to reach confluency. The cells were counted using a standard protocol utilizing the Trypan blue assay to assess the quantity of cells grown in media exposed to both environments. This was accomplished by harvesting cells from a replicate plate by incubating them in 0.25% trypsin-EDTA followed by centrifugation at 300x g for 10 min. The resulting pellet was suspended in 1 mL PBS, pH 7.4, and 15µL 1% Trypan blue and then counted by pipetting 15µL of solution into a haemacytometer. The average cell counts for each trial per condition were imported into SPSS for statistical analyses.

4.4 Results

Statistical analyses were conducted to assess the indirect effect that a powerful magnet may have on cell growth when only the media was pre-exposed to a static magnetic field for a prolonged duration of time. Kolmogorov-Smirnov's test deemed both groups to be normally distributed. Levene's test indicated that homogeneity of variance was not significantly different between groups. On average, the number of cells present in media exposed to the magnet (260.57 ± 9.66) was greater than the number of cells present in of media where the magnet was absent (204.22 ± 17.05). Oneway analysis of variance revealed this difference was significant [$F(1,13) = 9.690$, $p<.05$, $\omega^2 = 0.43$]. The graphical representation of this result can be viewed in Figure 6 below.

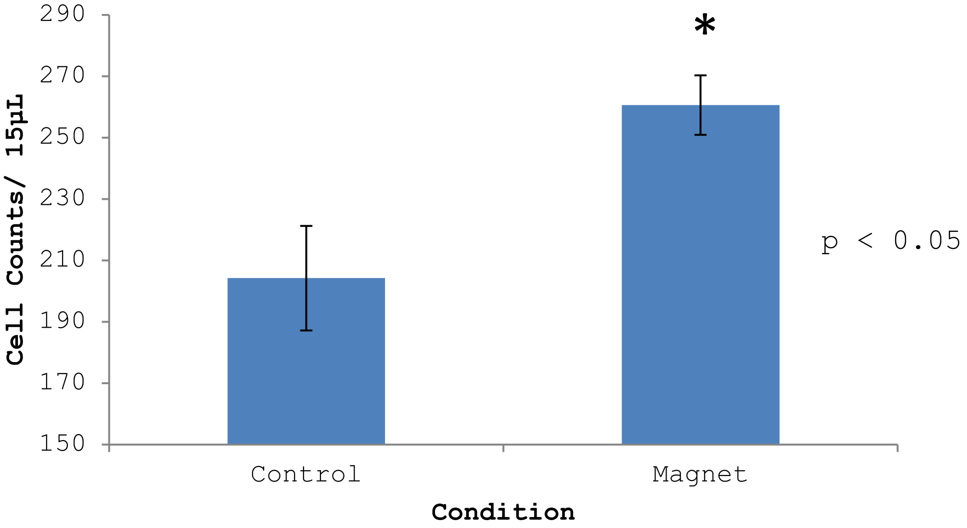

Figure 6. Average number of cells grown in of media pre-exposed to a magnet or a control (no magnet) condition. Error bars represent standard error of the means (n=5).

Statistical analyses were also conducted to determine whether there was an effect in the number of cells grown in the media positioned at the different poles of the magnet. A Kolmogorov-Smirnov's test deemed both groups to be normally distributed. Levene's test indicated that homogeneity of variance between groups was not significantly different. On average, the number cells grown in media pre-exposed to the South Pole of the magnet (269.887 ± 15.212) was greater than the number of cells grown in media pre-exposed to the North Pole of the magnet (251.262 ± 12.034). However, oneway analysis of variance revealed that there was no significant difference between the cell counts between the different media pre-treatment conditions [F(1,8) = 0.922, p>.05].

4.5 Discussion

The results of this study are quite interesting and, to the author’s knowledge, appear to be very rare in this field of research. Previous research indicated that the growth of cancer cells (Raylmann et al., 1996; Sabo et al., 2002; Tofani et al., 2001), including B16-BL6 mouse melanoma cells (Buckner, 2011; Buckner et al., 2015), were all inhibited when directly exposed to a magnetic field. Although these studies employed different cancer cell lines and magnetic fields with different patterns and intensities, the common theme among them was the reduction in cancer cell growth in response to direct exposure to a magnetic field. This phenomenon may be due to an increased influx of calcium ions. Buckner (2011) further suggested that a decrease in pH may have also played a prominent role in cell growth inhibition. However in the current study, it is evident that the growth of B16-BL6 mouse melanoma cells was enhanced in cell plates isolated in the dark that contained media that had been previously exposed to a strong static magnetic field (0.16 T) for 24 hours a priori as compared to controls. The cells were never directly exposed to the magnetic field. This corroborates many studies that have used magnetized water to treat seeds or various plants. Hozayn and Quados (2010) reported roughly a 10% increase in the growth of a chickpea plant when it was treated with magnetized water (water exposed to a magnetic field). According to the authors, there was also the expression of new proteins in the plants treated with magnetic water which appears to correlate with the increase in plant growth. Other studies of this nature support these claims (Belyavskaya, 2001; Celik et al., 2008; Shabrangi and Majd, 2009). Hafizi et al. (2014) noticed an increased number of corpus lutea as well as an increased height in epithelial cells lining the fallopian tubes of mice that drank magnetized water. It is possible that the magnetized media is also promoting cell growth by inducing a greater metabolic activity, as hypothesized by Belyavskaya (2001). This may have been accomplished by enhancing the reactivity of the nutrients found inside the medium, making them more readily available to the cell. According to Moore (1979), the standard medium employed in cell culturing experiments contains an excess of the required nutrients. He further adds that non-nutritional agents, such as magnetic fields, may increase cell permeability, cell respiration, decrease the formation of toxic metabolites, or even counteract the effects of growth-inhibiting substances that can be found in the cell medium. A study of this nature was performed by Varga (1976) whereby they pre-exposed cell medium to a magnetic field for as short as 1 minute and reported an increase in bacterial growth. There is also the possibility that the magnetic field is organizing the structure of the media at a molecular level, similar to how water is structured under the influence of a magnetic field. Although the mechanism for these effects remains unknown, the results of this study further corroborate previous research indicating the capacity of magnetic fields to increase cellular growth, although this is species dependent and magnetic field dependent. Future experiments should include assessing the number of dead versus living cells. Although there was an increased number of cells in plates exposed to a magnetic field, it is uncertain whether there would be more living cells compared to dead ones. This may help determine if the magnetized media is promoting cell survival. Also, it would be prudent to assess the physiochemical properties of the cell media before and after magnetic field exposure. This would help ascertain the notion that the magnetic field is affecting the physiochemical structure of the media, which may lend credence to the effects on the biological matter housed within it.

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Chapter 5 – General Discussion and Conclusion

Water has been present on Earth since before the abiogenic period. This was a moment in time where the early molecules of life were formed, whether they are amino acids (Miller, 1953) or nucleic acids (Rich, 1962). A key feature that is required for life is replication. Regardless of which molecule was present first, it is still unclear how these molecules aggregated together to form a larger polymeric molecule capable of self-replication. Cole and Graf (1974) have suggested a theoretical mechanism that may shed light on this question, although it is more related to Miller's primordial soup hypothesis. They hypothesized that the primitive Earth's geomagnetic field, present since Earth's inception and generated by convection of the molten core, may have been responsible for providing the appropriate alignment for the newly synthesized amino acids within Earth's seas required to facilitate the alignment and polymerization required for the synthesis of proteins. The Earth's magnetic field may have also been responsible for providing these molecules with their preferred stereochemistry, hence the almost exclusive appearance of L-amino acids in proteins. The Earth's electromagnetic field possesses both a static and a time-varying field component, where the intensity of the static field is greater than the electric field. The static electric field and the static magnetic field of the Earth’s geomagnetic field propagate together in a parallel fashion, whereas the time-varying sinusoidal electric field and magnetic field are perpendicular to the static fields. In this particular instance, the static fields are described to be capable of aligning the negatively charged terminal carboxyl group of amino acids at the water’s surface, similarly to a buoy. Subsequently, the alternating field could modify the stereochemistry of these amino acids by rotating them, favoring the L-conformation.

How do the current studies support the idea that exposure to electromagnetic fields can be a potent force in directing abiogenesis? Chapter 2 demonstrated that spring water, under the influence of a powerful static magnetic field in the dark, is capable of producing a greater quantity of an aggregated precipitated crystal structure as compared to controls lacking the magnetic field. It is important to note that similar crystals are present in sham-treated controls, just at much lower levels. This would imply that the magnetic field is not required for the process to occur, but that it accelerated crystal nucleation and/or growth. The morphology of the crystals formed was also dependent on the type of energy used to treat water. For example, when the spring water was exposed to heat, a different form of energy, the produced crystals formed a precipitate at the bottom of the flask. These crystals had the appearance of sharp pointy spears. However, when the water was exposed to a static electromagnetic field condition, the aggregated crystals formed at the surface of the water in an orderly fashion, similarly to what was proposed by Cole and Graf (1974) who hypothesized that the polymerization of amino acids occurred at the water's surface. This may explain why the crystals in the magnetic field condition have only been forming at the water's surface. The calculations in chapter 2 determined the amount of energy of the magnetic field that was able to affect the molecular structure of water. This energy was able to change the physiochemical properties of the water, which in turn could influence the solubility of organic material dissolved within it. A follow-up experiment would be to repeat this procedure, but with a solution of water containing biologically relevant molecules such as dissolved amino acids to determine if this effect could promote aggregation of biologically relevant materials. It would also be prudent to assess the physiochemical properties of water before and after magnetic field exposure in order to validate this proposed change in structure.

The third chapter of this thesis describes a series of calculations that suggest the possibility that Earth's magnetic field can be implicated in supporting the process of abiogenesis. The idea was to determine the potential impact of the geomagnetic field on the rate of covalent bond formation in order to determine the amount of time that was required to generate all of the bonds necessary to produce a living cell. In this particular case, the structure of a eukaryotic cell, the human cell, was examined to determine the approximate amount of time (3.33 billion years) required to produce this cell with geomagnetic energy. The hypothetical duration of this process is consistent with the historical values projected by Vidal (1984) and Cavalier-Smith (2009) which ranges between 3.2 – 3.8 billion years. There are many external factors that were present on early Earth which could have affected this process, but the convergence of these values is still an interesting observation suggesting an important role for geomagnetic activity in the process of abiogenesis. The next step would be to take this set of calculations and verify that it is compatible with the earliest living organism to appear on Earth, which is suggested to be approximately 900 million years after Earth’s creation (Rosing, 1999; Ohtomo et al., 2014; Pearce et al., 2018).

The fourth chapter of this dissertation examined the indirect effects of a powerful static magnetic field on cell proliferation. This was accomplished by exposing the culture media, the habitat of cells, to the magnetic field prior to introduction of cells into the new environment. It was determined that the magnetized medium promoted cell proliferation as indicated by the higher cell counts found in cell dishes pre-exposed to the magnetic field. Previous research demonstrated an inhibition of cell growth when the cells were directly exposed to a magnetic field (Raylmann et al., 1996; Sabo et al., 2002; Tofani et al., 2001; Buckner, 2011; Buckner et al., 2015). It is interesting that pre-exposing the culture media to a static electromagnetic field has a different effect on cell proliferation from direct exposure to an electromagnetic field. This supports the idea that indirectly influencing the medium with a static magnetic field was the driving force responsible for the increased cell counts. It is possible that the abiogenic phenomenon occurred in a similar fashion, with the magnetic field causing physiochemical changes in the liquid water medium which enhanced the formation of new and bigger molecules found in the oceans.

The common theme present in every chapter of this dissertation leads to the notion that increasing the order and structure of water molecules, and hence their cohesion, due to the influence of an electromagnetic field such as the geomagnetic field may be a plausible mechanism for the emergence of life from simple molecules. This has been suggested by many researchers in recent years. Cole and Graf (1974) were among the first researchers to provide a detailed hypothetical mechanism explaining how the geomagnetic field may have played a role in abiogenesis. They suggested that it may have been responsible for providing the newly synthesized amino acids within Earth's seas with the appropriate alignment required to facilitate polymerization and the synthesis of proteins. Exposure to geomagnetic fields may have also been responsible for providing these molecules with their preferred direction of structural rotation, hence the almost exclusive appearance of L-amino acids in proteins. Verdel and Bukovec (2014) highlight the idea that magnetized water possesses magnetism and that this magnetism may be attributed to the enhanced proton transfer between water molecules via the Grotthuss mechanism. Ho (2014) suggests this transfer creates excited coherent water, or Coherence Domains, which serves as a "redox pile" due to the negative charge located at their periphery. The constant disparity of charges generates a difference in polarity within water that is capable of affecting dissolved or suspended solutes, facilitating their ordered coalescence as suggested by Pollack et al (2009). Pollack further proposed that a source of energy is required to create this environment. Del Giudice et al. (2010) suggested that the electromagnetic field could be the solution capable of driving separated molecules to a much closer distance. I made a similar observation by showing that an aggregated crystalline structure appeared in solutions of spring water, containing various dissolved ions and minerals, when exposed to a static magnetic field in the dark for several days. In short, although it is still highly speculative, it is possible that Earth's very own electromagnetic field may have catalyzed the emergence of life by affecting the water that surrounded the early abiogenic molecules, helping them connect together to form larger, self-replicating, biogenic molecules.

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