Water and Ions as the Conditions Necessary for the Presence of Life

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The Secret History of Life

By

Raul Cuero, PhD

Cambridge Scholars Publishing

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I dedicate this book to my colleague and friend, the late Dr. David S. McKay (PhD and former JSC-NASA scientist), and also to my mentors Professor Percy Lilly in the USA, Professor John Smith in the UK, to the late Dr. Eivend Lillejo (PhD and former USDA scientist), and to the late Dr. Don Kreutzer (Doctor of Medicine). To my colleagues and friends, the late Dr. Aldein Reine (PhD and former USDA scientist), John Whitney (engineer), Heladio Ibarguen (scientist and researcher at the MD Anderson Cancer Center in the USA), Dr. Shimon Barel (PhD and scientist in Israel), and to Dr. Cecilia Arturo (Doctor of Medicine). Finally, to all the members of the International Park of Creativity.

TABLE OF CONTENTS

PREFACE

My experience in carrying out research related to biogenesis on Mars, using regolith-simulant soil, inspired me to investigate deeper into the roles of metal ions and water in the sustainability of biological entities/life, especially how metal ions and water interplay for the emergence of life. My attraction toward this research has been so great that it has become one of the most enjoyable experiences in my scientific career. The results of this research have led me to think that metal ions such as iron, magnesium, zinc, and other ions, including sulfur, are part the foundations for sustainability of biological entities/life. Therefore, after reading this book we are able to have a better understanding why despite presence of water sometimes there is no trace of biological entities/life. Hence, the book explains that it is not water alone, but the combination of water and metal ions as the conditions necessary for life. This confirms the concomitant effect of water and metal ions for sustainability of biological entities/life. Thus, our wonder can be solved that it is about the chicken and the egg, and not about the chicken or the egg. Also, it seems that these metals are interacting amongst each other, forming a layer of scaffolding-like net structures in water, where biomolecules are synthesized toward development of biological entities/ life. This means that without the presence of metal ions, it is difficult for water alone to sustain biological entities/life.

Therefore, I am pleased to share in this book some of my scientific experiences of how metal ions complement water for sustaining biological entities/life. Finally, the unprecedented current interest of space made this book relevant for fundamental understanding of planets such as Mars becoming possibly habitable. Furthermore, the tangible expression of the current climate change in the world made this book a must reading in order to understand not only the current environmental dimension of the climate changes, but the possible scenarios this natural challenge poses to science, as well as to the apocalyptical perception by the common people about the future of the environment. The book also presents biomarkers and artificial intelligence as good technologies for identifying undetectable biological entities/life

CHAPTER ONE

COSMIC DUST IN RELATION TO BIOLOGICAL ENTITIES/LIFE

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Understanding the relationship between the presence of water and life requires an integrated approach that encompasses interpretation of the development of the universe after the Big Bang, as well as the formation and distribution of the elements as a source of energy within the cosmological nucleosynthesis context, prior to emerging of biological systems. Furthermore, we must remember that 90 elements supposedly are in the planet Earth (Burbidge et al 1957), though man is actually living within a vessel of elements. Therefore, comprehension of the relationship between (a) elements and/or ions and (b) life and water requires interpretation of the origin of the universe and its physical and chemical evolution within the context of Nature's Conservation Law. However, it is not the intention of the author of this book to present a narrative about the origin of the cosmos in full detail, since this is beyond his expertise, though he attempts to relate some basic knowledge of the importance of cosmic elements and their evolution in relation to water as a source of biological entities/life. Hence, cosmological nucleosynthesis must be placed as the center of grasping this correlation.

Thus, we can start by looking at the cosmological nucleosynthesis as the primary event to produce hydrogen, helium, lithium, beryllium, and boron. Undoubtedly, it is not coincidental that the sequential order of appearance of the different elements established the real footprint for making water a medium for sustainability of life. Thus, if we look at the first elements that were formed (i.e., He, C, N, O, F, Ne, Na) during the hydrogen burning, it is well-known that elements such as fluorine, sodium, and carbon are the main constituents of natural water, including oceans, seas, lakes, and rivers (Burbidge et al 1957). Nevertheless, let's not forget that oxygen is the main form of electron transport, not only in plants and animals but also in the atmosphere, which makes it essential for sustainability of life as well. Here again, who's first: the chicken or the egg? Or is it both?

Then, the sequential order continued with the production of O16 and Mg24, during the helium burning. Again, this is not a coincidence because O16 is the most abundant (99.7%) form of oxygen in nature, which accounts for one of the main elements for sustainability of life. Also, Mg24 is the most stable form of magnesium and it occurs naturally; thus, it is suitable for biological systems, and, as is well-known, it is the main element of the chlorophyll molecule used for photosynthesis. This implies that before expression of a form of life, either plant or animal, these elements might have been introduced to an aqueous medium for sustainability of life, and also these elements must exist under specific oxidation-reduction conditions.

Following the sequence after magnesium, other important elements for life appeared, such as Si28, S32, Al36, and Ca40. These elements are very important during the oxidation-reduction metabolic process, where the cellular systems build energy. From the cosmic development, these elements appeared during the stage of alpha process, which is where alpha particles are the basis of the four-structure nuclei.

If we apply the previous physical chemical process, it is clear that most of these first elements are exothermic, which means that the biological system does not need to provide energy to ionize them, so they will be readily suitable to carry out functions in the biological system. However, the appearance of the latest elements such as vanadium, chromium, and nickel, because of their toxicity, are not suitable for terrestrial biological systems. It is important to mention that these latest elements were formed during a high-energy process, when there was an equilibrium between the maximum temperature and density of the nuclei (protons + neutrons) at the iron peak. It is obvious that these latest elements are endergonic, so they require energy or ionization, which the biological system cannot provide. Hence, they cannot be used by the biological system, which explains why they become toxic to living organisms and the terrestrial environment.

Therefore, this initial process provides sufficient energy to form atomic nuclei and consequently create the blueprints for the solar system.

Furthermore, a subsequent physical and chemical evolution will take place for the generation of atoms, molecules, and, finally, life.

In order to provide the reader with a better understanding of the natural and inherent interaction between elements during their evolution in water toward sustainability of biological entities/life, the author of this book shares here some basic fundamentals on the initial composition of planets in the solar system, including Earth and Mars, especially Earth's hydrosphere, biosphere, and sedimentary column, in which this column is known to sustain biological entities/life. Thus, some authors have studied hydrodynamic escape of gases from the atmosphere of an inner planet, which contributes to elucidate the planetary atmospheric conditions such as Mars (Hunten et al 1987). However, there have also been some mathematical and/or computational modeling for establishing the interaction between the time-decaying flux of extreme ultraviolet (EUV) radiation from the solar system (Pepin 1991). Thus, this links the chronology of dissipation of primary atmospheres, in relation to the presence of gasses, and other evolutionary phases of the atmosphere. Also, these concepts were linked to the EUV and/or rate of energy flow of particle radiation, which could have been a few hundred times greater than the present solar radiation and therefore adequate to accomplish escape energy demands and change Earth's atmospheres by hydrodynamic escape at approximately 50 million years (Pepin 1991).

Furthermore, the presence of hydrogen-rich primordial atmospheres considered to be at high temperatures and high altitudes were also analyzed in this model by Pepin (1991), after the nebula has been depleted due to the EUV radiation from the solar system. This type of model also analyzes the effect of the hydrogen escape fluxes on the other atmospheric constituents at a rate that would displace them based on their mole fractions and masses. For instance, fluxes of hydrogen escape at such a high level that they are able to displace and fractionate some present atmospheric elements at a much greater rate than can be supplied by the present solar EUV radiation (Pepin 1991). Furthermore, this model could be a good tool for establishing a sounder relationship between ions in the presence of water toward sustainability of biological entities/life. In fact, this model could be utilized for future computational modeling of a specific and predictable interaction of ions in water to sustain biological entities/life under extreme terrestrial and extraterrestrial conditions. Some parameters used in these models have been partially considered by the author of this book (see Chapters 7 and 8).

Also, in his model, Pepin (1991) relates the elemental nuclidic abundances based on gram units as solar composition matter, although helium is not strongly bounded in the atmospheres of the terrestrial planets, and also it is less relevant as a blueprint of the origin and early evolution of some of the planets in the solar system. Nevertheless, helium components exist inside of planet Earth, as well as in meteorites. Furthermore, the model by Pepin (1991), when using isotopic composition in the ancient sun and solar nebula, suggests that it is difficult to have consistency in the compositions of elements. In fact, there are differences of thought when it comes to the ratio compositions of carbon and nitrogen (Pepin 1991). This suggests that carbon and nitrogen, which are two of the main elements in any biological system, are difficult to precisely determine at which point of the evolution of elements they actually became part of the biological systems. Nevertheless, the author of this book presents in Chapter 3 scientific examples of the presence of carbon and nitrogen, suggesting when and how they became part of the biomolecules.

Other authors have also made great contributions to elucidate the planetary atmosphere compositions. Thus, these authors report that the biosphere, hydrosphere, and sedimentary column contain fractions of some of the atmospheric composition, ranging from non-noble gases (including Xe) to N, C, and H, which have been found on the upper terrestrial mantle over geological time (Bernatowicz et al 1984, 1985). Furthermore, Fanale and Jakosky (1982) and Fanale et al (1991) complement this information by reporting that the cold megaregolith for H_2O and CO_2 on Mars are low in the atmosphere, ice caps, and layered deposits. Additionally, Fanale and Jakosky (1982) and Fanale et al (1991) report that the Martian volatile atmosphere is susceptible to lose N_2 to space. Perhaps these views help us better understand why biological entities/life can be elusive despite the presence of water under certain extreme conditions, such as found on Mars, since nitrogen is one of the main components of biomolecules in biological entities/life. Perhaps, availability of nitrogen would stimulate presence of biological entities/life, depending on other atmospheric components.

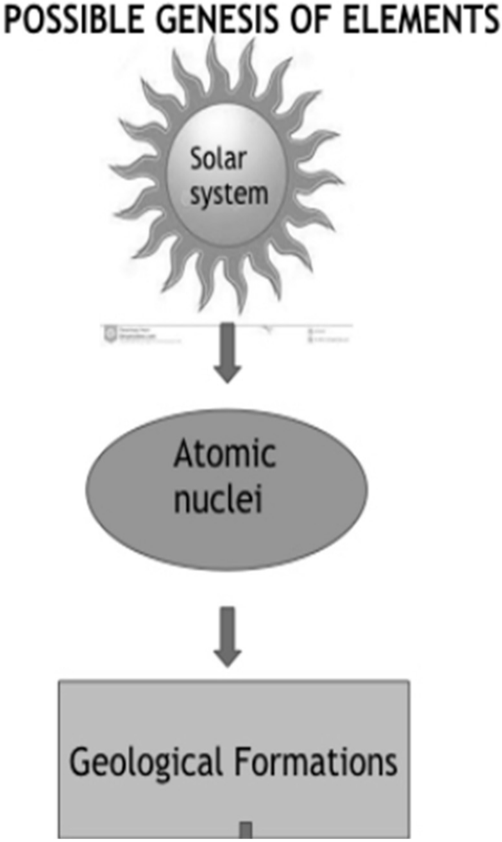

Figure 1. Hypothetical view of the possible genesis of elements in relation to biogenesis.

Looking at the evolution of the cosmos, it is clear that at the beginning of the universe, particles such as elements were the only components of matter, as shown in Figure 1. The author suggests this hypothetical illustration of the simple genetic evolutionary process, in relation to biogenesis, of the elements after the Big Bang and just before the Supernova. The image illustrates a hypothetical view of the evolution of the elements until they become part of the biological system. Therefore, these elements were the source of energy for the later formation of biocomplex molecules made of carbon, nitrogen, phosphorous, and iron, so that more complex molecules became assembled. Now, the question is: Were the elements initially bounded to these biomolecules? Or were the elements bound to the water molecules first, in order to sustain life? Consequently, these elements and/or ions became the necessary source of energy for the sustainability of living systems. This energy was supplied as dust by nuclear reactions taking place in the stars.

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CHAPTER TWO

WATER AS THE MOST SUITABLE DILUENT FOR SUPPORTING BIOLOGICAL ENTITIES/LIFE: FUNDAMENTALS

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Undoubtedly, water is the most suitable diluent for biomolecules related to supporting biological entities/life. However, the question is: Is water important to sustain biological entities/life because of its liquid wetness nature or because of its chemical composition, such as relating to ions? The answer to this question is the essence of this book, in which the author doesn't attempt to give a full answer to the question but instead gives a brief and approximate understanding of this compelling scientific and intellectual perspective. This is especially relevant nowadays when the advanced science and technology have been able to find the presence of water but also the absence of biological entities/life in some terrestrial and extraterrestrial environments. Perhaps, this book and/or chapter might not give the final, conventional/orthodox logical answer, but it will provide the reader with a better understanding and a more compelling perception that biological entities/life are not necessarily what we think. Hence, it is not what our conventional, pragmatic, deductive, and/or Newtonian perception of what defines real life, but rather the sum of different integrating components including biological, chemical, geological, biophysical, biochemical, and even intellectual interpretations that may be called a biological entity instead of the commonly used narrow singular approach of "life" itself. Therefore, this integration of different elements constitutes the complementary presence of the "chicken and the egg, rather than the chicken or the egg."

Therefore, it is important to give a deeper perspective of the function of water compared with the general perception of this liquid molecule. For instance, the general view is that water is the unique compound credited to be the indicator of the presence of potential for life in terrestrial and extraterrestrial environments. It is known to be the most universal solvent, and the major constituent in our bodies and in all living organisms. Typically, it is one of the first words learned by children, in addition to mom and dad, and thus children become unconsciously familiar with the H_2O formula, even without having been to school.

Also, it is a general understanding that water is the common solvent that mediates the changes of state of most solid earthen materials, the life cycles of rocks, and the creation of soils that enter living organisms through plants, microorganisms, and animals, and eventually become part of all the biological entity systems, including humans. Even the return of the body to the earth is mediated by water in the decomposition of organic matter. Furthermore, water is the central medium of our weather cycles; it is the mass and energy transfer medium from the oceans to the atmosphere, land, soil, and the flowing liquid streams returning to the reservoir of earth materials that compose the material source of life as we know it. Water in crystals is a constituent of many of the "rock solid" minerals. It is 99% of the amniotic fluid in which every human life begins and passes through the preceding stages of cellular, structural, and functional development similar to all life.

After the above general perspective of water, it is necessary to understand physicochemical properties of water in order to better elucidate how it alone is able to support biological entities/life. Hence, taking a look at water as a diluent, we must understand what causes it to be a liquid at room temperature, while diatomic hydrogen and oxygen are both gases at the same temperature, despite diatomic oxygen having an even larger mass than water. This can be understood by the difference in electronegativity of hydrogen and oxygen, where oxygen is one of the most electronegative elements on the periodic table and requires two electrons to complete its valence shell; whereas hydrogen reaches a lower energy state by losing an electron. Thus, two hydrogen and one oxygen atoms share their electrons to complete all of their valence shells. However, since oxygen is so electronegative, it holds onto the shared electrons most of the time, making the water molecule a dipole, where the oxygen side is slightly negative and the hydrogens are slightly positive. Furthermore, oxygen has a tetrahedral valence shell while hydrogens cannot bond directly across the oxygen.

Hence, the two hydrogens are on one side and oxygen is on the other, which causes an electrical imbalance. This imbalance reaches a lower energy state by having positive dipoles near negative charges. Similarly, this also happens in a nearby water molecule at the oxygen side. Hydrogen and oxygen atoms from other water molecules interact with each other to create the phenomena of hydrogen bonding by temporarily bonding with each other in bulk, consequently preventing water molecules from escaping into a gaseous state. This hydrogen bonding is what makes water the universal solvent, as it can easily surround and hydrogen-bond with the charge disparities in other molecules, lowering their energy state with charge compensation (Millero 2000).

Understanding the above fundamentals allows us to connect the dots on how metal ions in water are intrinsically dependent toward supporting the development and/or survival of biological entities/life. Therefore, this requires a closer view of the origin of ions and the presence of water. It has been hypothesized that water on Earth originated from the outer layer of the solar system in a late period of history. However, most recent studies point out that hydrogen has been important to the formation of the oceans (Pepin 1991). In fact, isotopic ratio studies of deuterium to hydrogen have been proposed as indicators of the origin of water on Earth (Hagemann et al 1970). Furthermore, it is known that despite iron being found at lower concentrations in oceans, it seems that in early periods it was one of the first elements that arrived in the ocean from the atmospheric cosmic dust. Perhaps these views help us understand why it has been suggested that biological entities/life might have first emerged from ocean environments. Looking at the general pH of the ocean (>7), as well as its wider composition of ions, we could take this concept as valid. Generally, the two main types of ions in water are hydronium and hydroxide, and salt ions such as sodium and chloride. One of the roles of ions in water in relation to biological entities/life is to facilitate hydrogen bonding. Thus, if the solution pH is beyond the necessary range of certain proteins, they can be denatured due to the breakage of the hydrogen-bonding structure. Likewise, salt ions can similarly disrupt the hydrogen bonding that is necessary in many protein structures. Also, high temperatures can destroy these hydrogen bonds, and consequently affect the structure and/or function of the protein (Galamba 2013), which are very important in the sustainability of biological entities/ life.

The ion–water relationship can be observed since earlier times when Earth was younger and less massive, and water could have been easily lost to space. Hence, lighter elements such as helium and hydrogen could have continuously escaped from the atmosphere (Pepin 1991). Hot volatiles in early times appear to have created an atmosphere comprising carbon dioxide, hydrogen, and water vapor. Consequently, this resulted in liquid water despite the high surface temperatures (230ºC), due to the higher CO_2 atmospheric pressure at that time. This CO_2 started to dissipate from the atmosphere as a result of subduction and dissolution in ocean water (Sleep et al 2001). However, it might have appeared from the beginning of Earth's formation. In the process of searching for biological entities/life, as well as any chemical fingerprints, it is very important to relate the role of geological entities in order to make a distinction from biological entities. This could perhaps be achieved by looking at the water isotopic ratios for chemical fingerprinting. Hence, using the isotopic deuterium-to-hydrogen ratio has provided a good tool for searching for the origin of water on Earth, as mentioned above. Thus, hydrogen is the most prevalent element in the universe; however, the hydrogen atom in H_2O can be replaced by deuterium (Yang et al 1984).

In Chapters Four and Five, the author of this book provides further description of the relationship of water and ions pertaining to biological entities/life.

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CHAPTER THREE

THE IMPORTANCE OF METAL IONS IN RELATION TO WATER FOR THE SUSTAINABILITY OF BIOLOGICAL ENTITIES/LIFE

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In the following chapter, the author tries to put into context within a practical approach the importance of metal ions in making water suitable for sustaining biological entities/life. Thus, this can be illustrated by using the formula:

FORM = FUNCTION

This simple formula indicates that form and function are interchangeable if we consider that form is mass and function is energy. Perhaps, this interchangeable mechanism of mass to energy and energy back to mass, which is the basic formation of the stars in which considerable mass is converted into energy, can be the case for explaining how living systems were developed in water under the influence of energy generated from elements. Therefore, before the formation of any cellular biological (form/mass) system, it was necessary to establish an energy transport mechanism via proton/electron mediated by elements within a liquid milieu such as water, as the examples described below. Hence, it is pertinent to think that this milieu (water) must have a specific type of energy system in order to sustain forms of life.

Perhaps, this explains why in planets different to Earth, life does not obviously appear despite the presence of water. Here again, which first: the chicken or the egg? Or both?

Thus, the approach toward this understanding is to look at the importance of water as a medium or milieu, composed of ions under certain physicochemical states (i.e., oxidation/reduction) as the key for energy and/or electroconductivity; hence, transporting necessary energy for the biological entity to carry out the main functions for survival. Otherwise, the absence of these ions will exclude the milieu of the necessary energy for sustainability of biological entities, and thus the water becomes nothing but a source of wetness. Furthermore, it seems that the metal ions, during the transition of the prebiotic and biotic eras and perhaps even today in an undisturbed aqueous medium, interact amongst each other forming a layer of scaffolding-like net structures in water, where biomolecules are synthesized toward the development of biological entities/life (Figure 3.1a–b). This means that without the presence of metal ions, it is difficult for water alone to sustain biological entities/life. Therefore, the author attempts to provide a pragmatic and more sensitive approach for detecting natural biomolecules and/or biological entities at the minimum level of concentration in water under extreme conditions. Extreme conditions have conventionally been defined as an excess or scarcity of certain factors, including extreme temperatures, salts, gases (i.e., oxygen and carbon dioxide), solutes, pressure, and pH levels. Hence, despite the extremes of these factors, they are all related to the flow of free energy for supporting life/biomolecules/biological entities. It is known that extreme conditions lead to extreme oxidation and reduction, restricting the free energy necessary to express biological entities/life despite the presence of water. This is due to the lack of electron flow, also known as free energy, which is the mediator of any biological activity. Thus, the author uses the concept of Gibb's Free Energy Law, which is related to free flow of energy during the oxidation reduction process, yielding electrons (energy) (Gibbs 1873). Hence, it helps us better understand how ions are key factors for supporting biological entities in water, based on ionic oxidation/reduction for free energy activity, using the Gibb's Law (see Figure 3.2). Therefore, in order to understand the relationship of water ions and biological entities, the author may use an integration of basic knowledge, such as physical and chemical laws, and geochemical, molecular, evolution, and microbiological fundamentals.

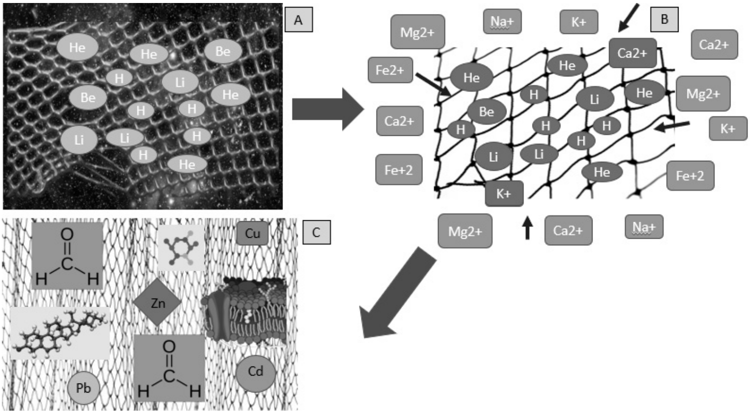

Figure 3.1a

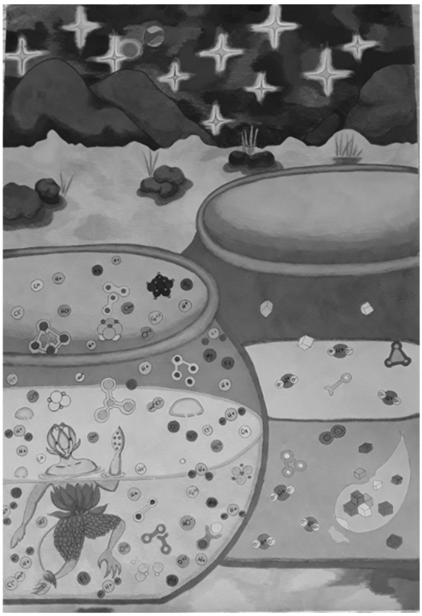

Figure 3.1b

Figure 3.1a–b. Hypothetical illustration of how metal ions interact amongst each other in forming a scaffolding-like net structure in water during the transition of prebiotic and biotic times, and perhaps even today in an undisturbed aqueous medium.

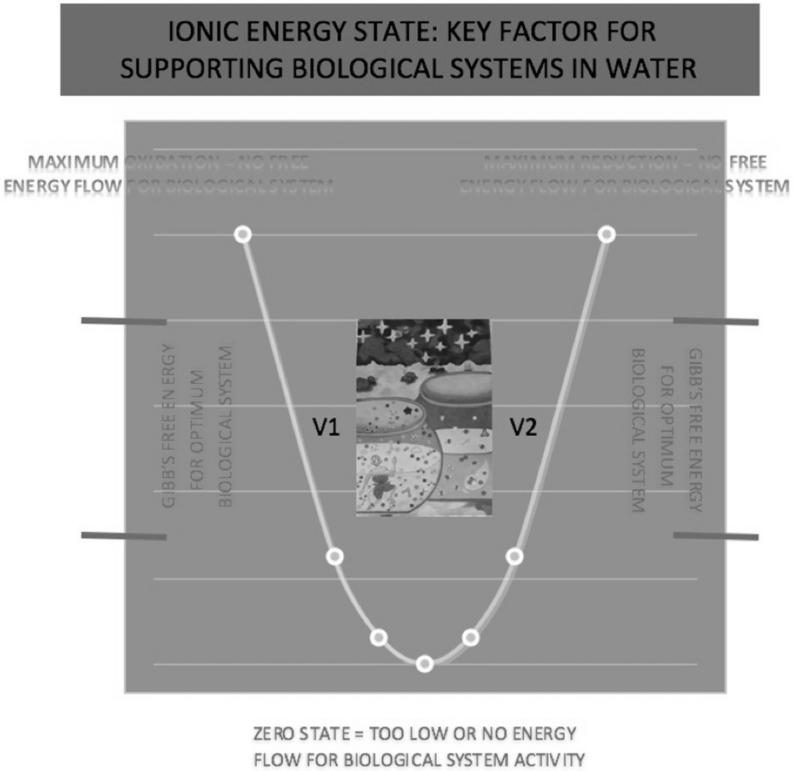

Figure 3.2. Hypothetical illustration of how ions are key factors for supporting biological entities in water, based on ionic oxidation/reduction for free energy activity (Gibb's Free Energy Law). This illustrates a maximum oxidation (upper left side) and maximum reduction (upper right side), in which there is no life sustainability due to the lack of free energy flow. Conversely, the middle of the figure (in between the blue lines) shows the presence of ions in a state of flow energy, thus supporting biological entities/life.

The presence of metal ions in biological entities is also well expressed in plant systems. There are many examples of how the elements could be considered as driving forces for the sustainability of plants. Thus, it is plausible to share a basic example of how ion elements contribute to the basic mechanisms (plant photosynthesis and respiration) for plant development and survival. In fact, the example described below (Figure 3.3) also sheds light on understanding why plants evolved before animals, including human beings. Therefore, the example relates the effect of ions on photosynthesis and restoration of plants, and consequently on environmental sustainability.

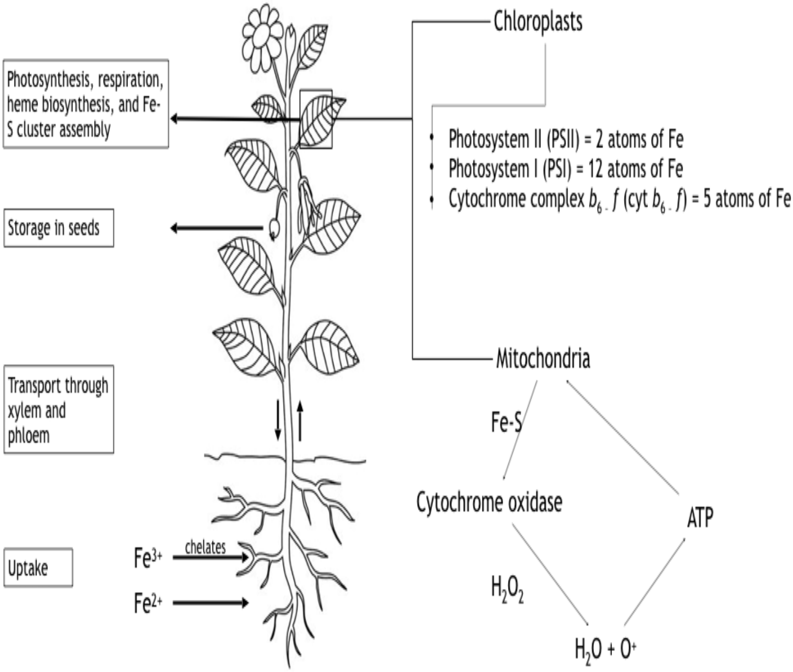

Figure 3.3. The effect of iron on plant biogenesis and development, and consequently on environmental renewability.

Figure 3.3 illustrates how iron is taken up by the roots of the plant through means of reduction (i.e., Fe^{2+}) or chelation (i.e., Fe^{3+}). Then, iron is transported by xylem and phloem to the sinking tissue (sites of iron-dependent enzymes), like in leaves (Connorton et al 2017). Also, iron is found in the chloroplasts and mitochondria in the leaves for carrying out photosynthesis and/or respiration, as well as heme biosynthesis and Fe-S cluster assembly (Krohling et al 2016). Thus, iron is used for photosynthesis in the chloroplasts, and hence two atoms of Fe are used for Photosystem II (PSII), twelve atoms of Fe for Photosystem I (PSI), and five atoms of Fe for Cytochrome complex b_{6-f} (cyt b_{6-f}). Iron is also found in mitochondria to carry out the restoration process, where one of the irons is used by cytochrome oxidase to oxidase H_2O_2 to form H_2O $^{+}$ O^{+} which is used to produce adenosine triphosphate (ATP) (Morrisea and Guerinot 2009). This all occurs within an aqueous medium.

The ionic interactive mechanism in plants is a good example of the influence of these ions on biomolecule development and the sequence of the presence of the elementary particles such as hydrogen, and elements such as iron; thus showing the importance of metal ions to establish a continuous energy flow, including the proton-hydrogen pump that becomes the main source of energy to carry out vital biological processes, such as photosynthesis and respiration. Also, it is known that in all organisms, energy is stored in electrochemical ion gradients across biological membranes, and used for solute transport and for synthetic processes like ATP synthesis. Electrochemical gradients are mainly generated by vector membrane reactions, such as electron transfer from one side of the membrane and proton uptake from the opposite side, and/or by pumping ions, normally protons, across the membrane using the energy of light or of chemical processes such as ATP hydrolysis or redox reactions. Likewise, heme- and copper-containing terminal oxidases (HCOs) function as cytochrome c oxidases or as quinol oxidases in aerobic respiration, and they also play a role in oxygen scavenging and maintaining redox homeostasis by coupling the exothermic four electron reduction of O_2 to H_2O with proton pumping (Buschmann et al 2010).

Therefore, the examples described above give us a better scientific understanding of the importance of elements such as iron for the sustainability of life (i.e., plants). Hence, it is clear that the iron–copper–sulfur complex plays a crucial role as a source of energy for initial biomolecules such as enzymes and for energy transport during the initial stages of plant formation, as well as movement of energy in the form of electron-proton for oxygen and/or hydrogen availability; and consequently it results in the formation of molecular water, which is the main milieu for the sustainability of life. Then, here we go again: which is first, the chicken or the egg? Or is it the chicken and the egg?

Inevitably, the question that arises when trying to elucidate the influence of metal ions on biological sustainability in relation to water is: When and why did metal ions become part of biological entities/life? It is known that metal ions have become one of the most important elements in the formation of stars and cosmic formation itself, including the development of biological entities/life. Using studies in infrared spectra, it is estimated that the appearance of metal ions dates back to about 500 million years after the Big

Bang during the Precambrian time, in which elements with low mass and luminosity were found and their development in the energy spectrum of matter, the generation of voids, and the natural cosmic filaments of the universe was determined (Burini et al 2018). Hence, the interaction of metal ions with biological entities begins with a destabilization in the covalent indexes and bonds of molecules more than four billion years ago in the Hadeon eon, which is when the solar system was in formation producing molecular clouds as well as gases and dust. This generates a variation of the electronegativity and size of the atom; however, under specific absorptions and with emission of energy quantum, the surfaces do not behave as static templates. Thus, these molecular interactions produce new molecular species (Hamada 2016, Burini et al 2018).

Fundamentally, the introduction of metal ions to biological entities was expressed through thermodynamic reactions following a constant trend and equilibrium. Thus, showing the stability of metal ions or metal-ligand complexes in biological systems. Hence, it is presumed that those such as potassium, sodium, and lithium have been most easily introduced into biological entities, since they have a lower classification in terms of the donor electron. Nevertheless, this also means that their binding is directly related to the ionic index, which is a function of the charge squared of the atom in relation to the ion (Zeneli and Ajvazi 2020). Another possibility is that metallic ions have been incorporated into biological molecules because of their instability (transition and alkaline earth metals in particular), which facilitates oxidation and reduction reactions (Hamada 2016). This explains the maintenance of charge equilibrium and electrical conductivity. The interaction of these metal ions with biological systems at the molecular level is also expressed by analyzing the structure biomolecules, such as of amino acids. The metal ions that are on the side chain of amino acids generate specific properties and reactions, since they can act as “labels” for the active sites of enzymes, formation domains, redox potentials, and other physical properties including spectroscopic, optical, rotational, and magnetic (Holm et al 1996, Haas and Franz 2009). One of the chemical properties of these metal ions that facilitates their interaction in biomolecules is their positive charge in aqueous media, which can be adjusted according to the coordination environment; thus, the metal ions surrounded by ligands can be cationic, anionic, or neutral. Biomolecules such as amino acids have unique properties, like selectivity, in order to tune overall complexes or reacting metals.

In another aspect, the interaction between metal ions and organic ligands is favored by the different coordination geometries that allow for unique shapes, bond lengths, and bond angles, and coordination site numbers which vary depending on the metal and its coordination state. In addition, metal ions with high electronic affinity can significantly polarize groups coordinated to them, facilitating hydrolysis reactions (Rosei et al 2003). This inherited molecular coordination could be a consequence of the cosmic dust during the early universe after the great explosion, although the folding and coordination of the bonds were not yet established during this time. However, the product of this cosmic process was the dispersion of ions, electrically charged atoms, which were constantly exchanging electrons with the environment, seeking to establish its charge and structure (Haas and Franz 2009). Most metals were in ionic form, which allowed them to interact mainly with the not-yet-established carbon–hydrogen bonds, so creating coordination and structure to the molecule's information. Thus, different scientists propose metal ions with the identity of prebiotic catalysts that gave shape and structure by means of chemical ligands, to what are known today as organic and inorganic molecules (Tait et al 2008).

Unequivocally, the importance of metal ions in water toward the sustainability of biological entities/life cannot be understood without considering the molecular evolution. There are many scientific works that give a good account of this molecular evolution (Calvin 1969). For instance, the Fe^{+3} state facilitates the catalysis of molecules such as hydrogen peroxide to water and using oxygen potential, thus establishing a coordination with the metal. This process takes several steps to produce ferric ions as a byproduct, and this has led to the current process in which a compound in a cell is transformed, mediated by protein enzymes. Other reports confirm the transformation of reduced compounds/molecules as energetic substrates related to the origin of life using chemolithotrophs under high pressure and temperature in relation to molecular development due to underwater volcanic activity (Wachtershauser 2007). Furthermore, the role of carbon compounds such as CO, CO_2, COS, HCN, and CH_3SH, and FeS, which function as catalytic entities to the formation of biological compounds, has been also studied. Thus, allowing the oxidation of FeS to release Fe, S, H, and electrons leads to the reaction of CO_2 reduction to form complex chemical species (Burini et al 2018, Tait et al 2008). Therefore, metal ions may be considered not only as a precursor of molecular recombination but also as an important component in the redox activity within a thermodynamic view toward establishing binding sites as a function of changes in pressure and concentration.

Considering polymers such as nucleic acids and proteins as some of the most important biomolecules in biological entities/life, it is essential to consider the function of metal ions in relation to the origin of these molecules. Thus, metals are found in three different forms (i.e., carbonates, oxides, and free states) in nature, and when they are in a free state they provide the energy to trigger the biological activity through substitution and/or coordination complex to form biomolecules and/or polymerization of nucleotides. For instance, it is known that transition metals form ligand biomolecules. Similarly, protein enzymes can be recognized as a result of this original interaction, and the different combinations of sequence analysis, structure, and shared metabolism allow the coordination of metal ions for protein activity. Thus, this explains why the structural regions and amino acid sequences that coordinate the metal ions are usually highly conserved. A good example of this is the presence of sulfur in the first amino acid, methionine, which has the ability to retain and bind to a metal center such as sulfur, despite being a short-chain amino acid. In fact, other authors postulate that metalloproteins known today originated as repeated sequences of short peptides, as well as being influenced by redox potential (Cooper et al 2011, Haas and Franz 2009). Furthermore, it is known that iron and sulfur group proteins are considered as ancient and fundamental molecules within the evolutionary context, including the synthesis of primary proteins and genetic material. Also, these proteins possess the ability to generate cluster coordination through electron interaction, which allows structural identification, and thus binding to primary sequences and allowing them to fully establish their group; this process will establish new forms of chemical folding.

Knowing the above concepts, the question arises of when these metal ions became integrated into the cellular system and/or biological entities/life. Hence, the first thought that comes across could be that these metal ions were enclosed by thin, fragmented layers that were later recognized as cellular membranes. However, there is a need to understand the importance of the presence of a membrane, and thus there are different approaches to explaining the primary origin of the membrane in relation to associated or complementary molecules toward maintaining an equilibrium in the system that started to evolve, as it required encapsulation. Hence, permeability was one of the main considerations due to the original environmental conditions. Therefore, the first approach was to conceive the membrane with a structure composed of RNA folds as a consequence of structural cohesion between trace elements and polynucleotides. The second approach was much more complex and more in agreement with how biological membranes are regarded today, as consisting of a type of lipid that might be related to fatty acids that were found in the meteorite rocks (Deamer 1985). This can also be synthesized under prebiotic conditions due to the presence of molecules such as CO, CO_2, and H_2, and gases under the presence of metal catalysts at high temperatures, which can give rise to long-chain fatty acids (McCollom et al 1999). It is important to understand that due to the amphoteric nature of lipids, they are able to spontaneously assemble into bilayer vesicles, showing their hydrophobic tails toward the interior part of the membrane, while the hydrophilic heads are facing outward.

In order to gain a better understanding of the mechanism of how metal ions interact amongst each other, as well as how they help to form complex molecules, the author attempts to refresh some fundamentals of ion dynamics. Hence, an ion is an atom that is not electrically neutral, and therefore it is electrically charged. It is understood that the ionizing character is determined by the electrons that are gained or lost during the ionization process. Ions can be classified into two types:

(1) Anion, which is an ion possessing a negative electric charge because the atom that gave rise to it gained one or more electrons. The main known anions are hydride ion H^-, fluoride ion F^-, chloride ion Cl^-, bromide ion Br^-, iodide ion I^-, and hydroxyl ion OH^-, among others.

(2) Cation, which is an ion possessing a positive electric charge because the atom from which it derives has lost one or more electrons. The main cations found are hydrogen ion H^+, hydronium ion H_3O^+, ammonium ion NH^{4+}, sodium ion Na^+, lithium ion Li^+, potassium ion K^+, silver ion Ag^+, calcium ion Ca^{2+}, and iron ion Fe^{2+}, among others.

It is fundamentally known that when forming salts, the most electropositive element is always represented first; for example: LiF, KI, NaCl, MgCl. From the polarization point of view, it is possible to establish the reactivity and ionizing compatibility of these metal ions, while the ionizing property establishes and defines the tendencies to interact with other ions. Most of the elements in nature, such as Na, K, S, and Li, have different oxidation states, allowing univalent cations to form. However, it is important to realize that metal ions are highly compatible with water in their ionic state, while alkali metals tend to be incompatible with water. Thus, what is called a hard ion is characterized by having a high density of a positive charge near the nucleus, and hence it is not easily polarized. Conversely, a soft ion possesses a low positive charge near the nucleus, so that a charge or electric field can