American Journal of Immunology

Original Research Paper

Experimental Evidence for the Role of Natural Radioactivity in Influencing Viability of Commensal Microorganisms

Marco Ruggiero

National Coalition of Independent Scholars, San Antonio, TX, USA

Article history
Received: 11-01-2021
Revised: 03-04-2021
Accepted: 11-05-2021

Email: marco.ruggiero@ncis.org

Abstract: To investigate the feasibility of culturing edible microbes, classified as probiotics for human consumption, in commercially available, naturally radioactive, mineral water; to compare their viability with that of the same microbes cultured in deuterium-depleted water. A diversified array of probiotics was cultured in two different naturally radioactive mineral waters, or in deuterium-depleted water in order to assess the effects of different culture conditions on microbial viability. Prebiotic microbes for human consumption (cyanobacteria) that are extremely resistant to radiations, were cultured together with the probiotics in a naturally radioactive carbonated mineral water containing silica from vegetal origin introduced to enhance horizontal gene transfer. This co-culture had the goal of transferring radiation resistance from the cyanobacteria to the probiotics. The experiments and the observations described in this study were conducted from April 2020 until March 2021. Culturing microbes in naturally radioactive mineral water yielded one order of magnitude more live microbial cells in comparison with culturing in deuterium-depleted water. *In silico* observations suggest that expression of DNA repair genes in cyanobacteria is induced by co-culturing conditions in a medium of carbonated mineral water naturally containing the radioactive isotopes ^{228}U and ^{226}Ra. The results presented in this study lay the foundation for the development of a novel approach to protection against electromagnetic fields comprising ionizing and non-ionizing radiations. *In silico* observations and preliminary results on subjects exposed to common electromagnetic fields under real-life conditions, support the hypothesis that co-cultures of radiation-resistant cyanobacteria and probiotics in naturally radioactive, carbonated mineral water may confer protection against the harmful effects of electromagnetic fields.

Keywords: Natural Radioactivity, Deuterium, Water, Probiotics, Cyanobacteria

Introduction

For more than thirty years, I have studied the biological effects of different types of energy, ranging from static magnetic fields to ionizing and non-ionizing radiations and ultrasounds, on normal and transformed cells in culture, embryos and organisms, with particular reference to changes in signal transduction, gene expression, cell morphology and clinical responses (Casamassima *et al*., 1989; Orlandini *et al*., 1991; Ruggiero *et al*., 1992; Vincenzini *et al*., 1993; Pacini *et al*., 1994a; 1994b; 1995; Chiarugi *et al*., 1995; Mazzanti *et al*., 1996; Santucci *et al*., 1996; Pacini *et al*., 1999a; 1999b; 1999c; Casamassima *et al*., 1999; Pacini *et al*., 2002; 2003; Ruggiero *et al*., 2004; Pacini *et al*., 2006; Ruggiero, 2008; Ruggiero *et al*., 2013; Bradstreet *et al*., 2014; Ruggiero and Aterini, 2015; Klinghardt, 2017; Branca *et al*., 2018). Certain types of eukaryotic cells, notably certain types of cancer cells (Vincenzini *et al*., 1993; Pacini *et al*., 1994a; 1994b; 1995; Chiarugi *et al*., 1995; Mazzanti *et al*., 1996; Santucci *et al*., 1996; Pacini *et al*., 1999a), show resistance to the killing effects of ionizing radiations, a phenomenon that, in the context of radiotherapy of cancer, may represent an obstacle to effective treatment (Casamassima *et al*., 1999). Most prokaryotic cells are sensitive to the killing effects of ionizing radiations and even to weak electromagnetic fields such as those generated by the physiologic electric activity of human cells *in vivo* (Ruggiero and Aterini, 2015). However, certain prokaryotes, such as cyanobacteria, exhibit extremely high resistance to the killing effects of ionizing radiations (Badri *et al*., 2015). A notable example is represented by Arthrospira platensis, a bacterium that survives exposure to gamma-rays up to 6,400 Gray units (Gy) with a dose rate of 527 Gyh^{-1} (Badri *et al*., 2015) [for comparison, the median human lethal radiation dose computed from data on occupants of reinforced concrete structures in Nagasaki, Japan, is around 3 Gy (Levin *et al*., 1992)].

In this experimental research study, I describe the behavior of commensal microbes classified as probiotics challenged with commercially available, naturally radioactive, mineral water. This investigation was prompted by the consideration that probiotics are consumed in increasingly large amount for their health supporting properties (Puértolas-Balint and Schroeder, 2020) and, since their efficacy lays in the ability to colonize the intestine, it is interesting to assess whether drinkable naturally radioactive mineral water affects microbial viability. The results obtained culturing an array of probiotics in naturally radioactive mineral water were compared with the results obtained culturing the same array of probiotics in deuterium-depleted water. Furthermore, the role of Arthrospira platensis in conferring radiation resistance was evaluated. This bacterium, in addition of being extraordinarily resistant to ionizing radiations, is considered a prebiotic since it favors the growth of probiotic microbes. Therefore, it can be hypothesized that co-culturing Arthrospira platensis with probiotics, in the presence of naturally radioactive mineral water, may yield information on possible horizontal transfer of information between radio-resistant and radio-sensitive microbes.

Materials and Methods

Radioactive Mineral Waters

Two types of commercially available, naturally radioactive, mineral waters were used. Analyses for minerals and radioactivity in both types of water had been previously performed and published by the Institutfür Pflanzenernährung und Bodenkunde, Braunschweig, Germany (Fleckenstein and Schnug, 2001). The first type of radioactive water, termed "A", was used to compare the viability of cells of an array of probiotics cultured in radioactive water *versus* the same probiotics cultured in deuterium-depleted water. Composition of the first water, termed A, as far as minerals and radioactive isotopes are concerned is the following:

pH	5.5
HCO^{3+}	483 mg/L
Ca^{2+}	486 mg/L
Cl^{-}	8.6 mg/L
Mg^{2+}	84 mg/L
Na^{+}	9.1 mg/L
K^{+}	3.2mg/L
SO^{4-}	1,187 mg/L
^{226}Ra	5.5 mBq 1^{-1}
Uranium	1.40 mBq 1^{-1}
Main minerals	2,181 mg/L

Radioactivity from ^{226}Ra + Uranium (^{238}U): 40.9 mBq 1^{-1}
Radioactivity from Uranium: 86%

The second type of radioactive water, termed B, was used for co-culturing Arthrospira platensis with an array of probiotics whose composition is described below. Composition of the second water, termed B, as far as minerals and radioactive isotopes are concerned is the following:

pH	7.84
HCO^{3+}	223 mg/L
Ca^{2+}	208.0 mg/L
Cl^{-}	68 mg/L
Mg^{2+}	53.5 mg/L
Na^{+}	42 mg/L
K^{+}	2.8mg/L
SO^{4-}	534.6 mg/L
^{226}Ra	152 mBq 1^{-1}
Uranium	217.7 mBq 1^{-1}
Main minerals	1,132 mg/L

Radioactivity from ^{226}Ra + Uranium (^{238}U): 369.7 mBq 1^{-1}
Radioactivity from Uranium: 59%

At variance with water A, water B is carbonated. The rationale to choose a carbonated mineral water with these values of natural radioactivity lays in the goal of stimulating adaptogenic responses in radio-resistant cyanobacteria that are known to up-regulate genes involved with DNA repair and protection as consequence of exposure to radiations (Badri *et al*., 2015).

Deuterium-Depleted Water

Deuterium-depleted water was purchased from Litewater Scientific (Reno, NV, USA). According to the Company's website (www.drinklitewater.com) this water has a 94-97% lower concentration of deuterium than regular water. This water is obtained from a natural artesian well in the Russian Federation, in the state of Tambov; it is purified by membrane technology and then processed by a method known as low-temperature vacuum rectification that is claimed to remove up to 97% of the deuterium in water.

Characteristics of the Probiotic Blend

The probiotic blend was kindly donated by Silver Spring Sagl (Arzo, Switzerland); it contains probiotic microbes that are members of the families of Streptococcaceae, Lactobacillaceae, Leuconostocaceae, Bifidobacteriaceae andThermaceae. The blend contains also lyophilized kefir grains that are characterized by a complex composition. The unique microbial composition of this probiotic blend is described in detail in two recent articles (Pacini and Ruggiero,2019a; 2019b). It has been observed that human consumption of this blend was associated with detoxification of non-metal toxicants (Blythe *et al*., 2017), decrease of serum alpha-N-acetylgalactosaminidase (nagalase) activity (Blythe *et al*., 2017; Carter *et al*., 2020), decrease of serum C-Reactive Protein (CRP) (Carter *et al*., 2020), decrease of markers specific for multiple myeloma (Antonucci *et al*., 2019) and decrease of viral load in Hepatitis B (Zunaid *et al*., 2020).

Determination of Microbial Viability in Radioactive Water A and Deuterium-Depleted Water

In one arm of the experiment, radioactive water A was used; in the other arm, deuterium-depleted water was used. 45 g of hemp seed proteins were added to 500 mL of each type water. The mixture of water and hemp seed proteins was boiled for 10 s; after that, it was cooled at room temperature (22°C). When the mixture had reached room temperature, the following ingredients were added: Lemon juice (7.5 g); cane sugar (25 g); apple cider vinegar (5 g); probiotic blend (2.5 g). The mixture was left at room temperature for a total of 48 h; after the first 24 h, the mixture was gently stirred. After that, the fermented product was gently mixed and then lyophilized using an apparatus provided by Zhengzhou Hento Machinery Ltd (Zhengzhou City, Henan, China). Yield was 12.64% for the preparation using radioactive water A and 12.69% for the preparation using deuterium-depleted water. The lyophilized powders, one containing the microbes cultured in radioactive water A and the other the microbes cultured in deuterium-depleted water, were then analyzed by an independent laboratory (Biolab Research Srl, Novara, Italy) for the count of viable cells using flow cytometry.

Method for Co-Culturing in Radioactive Water B

The method described here was for 1 L of product. As first step, the radioactive carbonated mineral water designated B was brought to room temperature (22-25°C). Then, the following ingredients were added: 40 g of Equisetum arvense; 40 g of white sugar; 16 mL of lemon juice; 10 mL of apple cider vinegar; 45 g of Arthrospira platensis; 10 g of the probiotic blend described above. Once these ingredients had been added, the solution was gently mixed by stirring at time 0, that is immediately after addition of the ingredients, 12, 24 and 36 h thereafter. Temperature of the mixture was maintained between 36 and 39°C for a total incubation time of 48 h. After 48 h incubation, the solution was gently mixed and lyophilized using the method described above. The method described above has been used as the basis for a proprietary procedure of fermentation aimed at manufacturing a supplement for human consumption designated "Praesidium" (Praesidium Life Limited, Auckland, New Zealand). Consistent with the method described above, this supplement contains fermented Spirulina (a biomass of edible cyanobacteria that encompasses Arthrospira platensis); fermented horsetail (Equisetum); sugar; lemon juice; apple cider vinegar; cultured kefir grains and the following probiotic strains: Bifidobacterium infantis, Bifidobacterium bifidum, Bifidobacterium lactis, Bifidobacterium longum.

Study of Amino Acid Sequences and Protein Structures

Study and comparisons of amino acid sequences, alignments and study of protein structures were performed using the dedicated programs developed by The Universal Protein Resource (UniProt) Consortium, a comprehensive resource for protein sequence and annotation data (UniProt Consortium, 2019).

The experiments and the observations described in this study were conducted from April 2020 until March 2021.

Results

Figure 1, shows the products obtained by culturing microbes in radioactive mineral water (A) and deuterium-depleted water, as they appear after lyophilization.

Determination of viable cells by flow cytometry demonstrated that, in the sample derived from culturing in naturally radioactive mineral water A, there were 2.36×10^9 viable cells per g of lyophilized powder; in the sample derived from culturing in deuterium-depleted water, there were 8.48×10^8 viable cells per g of lyophilized powder. These results demonstrate that viability of commensal microbes classified as probiotics is higher in a naturally radioactive mineral water as compared with deuterium-depleted water. It should be noticed, however, that the mineral composition of the two waters is different; therefore, further studies are warranted to ascertain whether the observed differences are due to natural radioactivity or other factors such as mineral composition.

Whatever the case, these results demonstrated the feasibility of culturing probiotics for human consumption in naturally radioactive mineral water with no apparent detriment to microbial viability. Therefore, based on these results, experiments were performed to assess the feasibility of co-culturing the probiotic blend mentioned above, together with Arthrospira platensis and Equisetum arvense, this time using a much more radioactive water, that is the water designated B, whose composition is described in Materials and Methods. The rationale for such an experiment lays in the continuous and simultaneous exposure to electromagnetic radiations (from natural radioactivity) and induction of photosynthesis from the Cherenkov radiation, a radiation that is a consequence of radioactivity in water. Thus, in the absence of Cherenkov radiation, cyanobacteria such as Arhtrospira down-regulate the genes presiding to photosynthesis when exposed to radiations such as gamma-rays and, at the same time, up-regulate the genes that protect them from the harmful effects of radiations (Badri *et al*., 2015).

Fig. 1: Appearance of the products of lyophilization of microbes cultures in radioactive mineral water designated A (left panel) and deuterium-depleted water (right panel). Culture conditions and procedure of lyophilization are described in the Materials and Methods. The two powders appear identical

In the experiment described here, however, induction of photosynthesis occurs concomitantly with exposure to radiations since induction of photosynthesis is caused by the Cherenkov radiation that in turn is due to the superluminal charged particles emitted by the radioisotopes present in the water. It is well known that the process of photosynthesis is based on quantum entanglement and, therefore, it can be hypothesized that up-regulation of genes involved in DNA repair and resistance to radiations and photosynthesis, become entangled. This may lead to further entanglement between the radio-resistant cyanobacteria and the microbes of the probiotic blend that are also exposed to the radioisotopes present in the water, but have no photosynthetic capacity; the mechanism at the basis of living bacterial entanglement following exposure to electromagnetic fields is explained in detail in Marletto *et al*. (2018). The choice of naturally radioactive water that is also carbonated lays in the well-known concept that carbon dioxide is required for photosynthesis and such a requirement is all the more significant when the source of light is represented by the continuum spectrum of Cherenkov radiation. Carbonated water shows a distinctive light scattering pattern that is very different from that of non-carbonated water. The presence of dissolved gas in the water leads to smoothing of the angular dependence of scattered light intensity and reduction of the polydispersity degree, thus optimizing the conditions for Cherenkov radiation-induced photosynthesis (Kovalenko *et al*., 2009). Such an optimization is due to the uniform distribution in the water of the radioactive isotopes of Uranium and Radium as well as to the equally uniform distribution of the bubbles typical of carbonated water. The constant, uniform, Cherenkov radiation is scattered by the bubbles and therefore reaches the light harvesting antennae of the cyanobacteria from all possible angles at variance with a common source of light that would reach the antennae from a fixed angle.

In short, the natural radioactivity in the carbonated mineral water evokes radio-protective responses as well as induction of photosynthesis in the cyanobacteria; through quantum entanglement, the cyanobacteria transfer the radio-protective response to the microbes of the probiotic blend that are also exposed to the natural radioactivity but are not radio-resistant *per se* and have no photosynthetic capacity. Preliminary observations reported by subjects using the supplement described in the Materials and Methods (Praesidium) support the hypothesis that the mechanism described above is at work under real-life conditions. These subjects, who were exposed to common environmental electromagnetic fields (house appliances, wiring, wireless communication devices), observed significant increase of Heart Rate Variability (HRV) associated with regular consumption of the supplement. Considering that electromagnetic fields such as those of wireless communication affect HRV

(Beres *et al*., 2018) and considering that high HRV is associated with reduced morbidity and mortality and improved psychological well-being and quality of life (Drury *et al*., 2019), these preliminary observation seem to indicate a protective effect against the harmful effects of electromagnetic fields. Further studies are in progress to elucidate a number of aspects related to these preliminary observations.

Discussion

Rationale for the use of Arthrospira Platensis

Arthrospira platensis has been used as food since the 16th century, because of its high-protein content and digestibility and it is now considered a prebiotic because it favors the growth of known probiotic microbes such as lactic acid bacteria [Lactococcus lactis, Streptococcus thermophilus, Lactobacillus casei, Lactobacillus acidophilus and Lactobacillus bulgaricus (Gupta *et al*., 2017)]. It is worth noticing that all these microbes are in the probiotic blend used in this study and co-cultured with Arthrospira in the naturally radioactive, carbonated mineral water designated B. Arthrospira platensis is endowed with strong anti-oxidant and anti-inflammatory properties that have potential applications in human radiation protection (Bhat and Madyastha, 2001). Consistent with its nutritional properties and its protective role against radiations, Arthrospira platensis has gained increasing interest for the nutrition of astronauts who are exposed to a wide range of electromagnetic radiations (Karkos *et al*., 2011). Arthrospira resistance to radiations is due to a number of factors that include the presence of high level of anti-oxidants and induction and up-regulation of genes involved in DNA repair. Among these, of particular importance in the context of this study, are the genes of the ultra violet radiation (*uvr*) family that are involved in the repair of Single Strand Breaks (SSBs) of DNA. DNA SSBs are the most typical DNA lesions observed after exposure to many types of electromagnetic radiations including those of mobile telecommunication (Mihai *et al*., 2014) and it is postulated that the risks for human health due to exposure to these electromagnetic fields derive from this type of genotoxic effects. To this point, the International Agency for Research on Cancer (IARC), after having evaluated the available scientific data, has classified the electromagnetic fields of mobile telecommunication as being “possibly carcinogenic” to human (IARC, 2002). These effects are of particular interest in the context of the fifth generation technology standard for cellular networks, which cellular phone companies began deploying worldwide in 2019. Although no studies are available on the direct effects of this new technology standard on human cancer onset and progression, a recent article analyzed 94 relevant publications performing *in vivo* or *in vitro* research on this topic. According to this meta-analysis, 80% of the *in vivo* studies showed biological responses to exposure, while 58% of the *in vitro* studies demonstrated effects (Simkó and Mattsson, 2019). Consistent with these observations, a study published in 2020 states that "*... the nascent mobile networking technology will affect not only the skin and eyes, as commonly believed, but will have adverse systemic effects as well*" (Kostoff *et al*., 2020).

Rationale for the Co-Culture of Arthrospira Platensis with Probiotics

The rationale for the use of Arthorspira platensis in co-culture with the probiotic blend described above consists in the following considerations. Ionizing radiations as well as electromagnetic fields used for mobile telecommunication and, in particular, high frequency fields used for the fifth generation technology standard, affect biological responses and are classified as carcinogenic for humans (IARC, 2002). The most common types of DNA damage due to electromagnetic radiations used for mobile telecommunication are SSBs (Mihai *et al*., 2014). This damage is repaired by proteins encoded by *uvr* genes and Arthrospira platensis up-regulates expression of *uvr* genes upon exposure to radiations (Badri *et al*., 2015). Arthrospira platensis is known to protect against radiation sickness (Mazo *et al*., 1999) as well as against the damage inflicted by electromagnetic radiations through DNA repair (*uvr* gene up-regulation) (Qishen *et al*., 1989). Naturally radioactive carbonated mineral induces up-regulation of radiation protection genes in Arthrospira platensis and Cherenkov radiation induces photosynthesis (Ran *et al*., 2012). Photosynthesis is based on quantum entanglement (Brookes, 2017). Electromagnetic fields such as those associated with charged particles from radioisotopes in the mineral water induce quantum entanglement between microbes (Marletto *et al*., 2018). Quantum entanglement and transfer of resistance to radiation between living organisms occurs in water (Mothersill *et al*., 2018). Therefore, Arthrospira platensis, a prebiotic bacterium already known to protect from radiation sickness, once exposed to (that is cultured in) naturally radioactive carbonated mineral water, activates mechanisms for DNA protection (*uvr* genes) that are known to protect against SSBs and transfers such a protection to probiotic microorganisms co-cultured in the same medium that in turn transfer such a protection to human cells through phages as described below.

As far as role of the probiotic blend is concerned, it is worth noting that the human microbiota is negatively affected by electromagnetic radiations of all types including those of mobile telecommunication (Crabtree *et al*., 2017). The probiotic blend contains a high number of live probiotic microbes with a high degree of biodiversity. Such a biodiversity reproduces the complexity of the human microbiota, thus reconstituting an organ that is essential for human health (Wallace *et al*., 2011). The probiotic blend also contains plasmids that are known to transfer biological information between bacteria (Pacini and Ruggiero, 2019a) and this feature is essential for exchanging biological information pertaining to radiation protection. In addition, the probiotic blend contains phages that are known to stimulate immunity, repair DNA and transfer biological information to human cells (Pacini and Ruggiero, 2019a). Independent of the route of administration, phages enter the bloodstream and tissues and interact with immune cells (macrophages, T-cells, Natural Killer cells, B-cells, granulocytes) (Van Belleghem *et al*., 2019). Phages have anti-inflammatory properties and inhibit excessive reactive oxygen species production (Górski *et al*., 2017) and it is known that excessive reactive oxygen species production is one of the consequences of exposure to electromagnetic radiations and is responsible for damage to DNA, proteins and cell structures (Kesari *et al*., 2011; Lu *et al*., 2012). In addition, the probiotic blend contains naturally formed Gc protein-derived Macrophage Activating Factor, a cytokine that stimulates/rebalances the immune system and, in the probiotic blend, is 100 fold more active than the chemically-obtained counterpart (Carter *et al*., 2020). Optimization of macrophage function is of utmost importance in counteracting the harmful effects of electromagnetic fields, including those used in mobile telecommunication, since exposure to these fields causes macrophage dysfunction (López-Furelos *et al*., 2018) that contributes to immune system disturbances (Johansson, 2009) that, in turn, contribute to some of the adverse health effects of mobile networking technology under real-life conditions (Kostoff *et al*., 2020). Ionizing radiations as well as non-ionizing radiations such as those used for mobile telecommunication cause excessive formation of reactive oxygen species that leads to apoptosis of human blood macrophages (Lu *et al*., 2012). The simultaneous presence of phages, that inhibit excessive reactive oxygen species formation (Górski *et al*., 2017) and Gc protein-derived Macrophage Activating Factor that stimulates human blood macrophages (Pacini *et al*., 2012), prevents these harmful effects of radiations on macrophages. In addition, the simultaneous presence of phages and Gc protein-derived Macrophage Activating Factor leads to optimization of immune system function at the same time preventing inflammation (Górski *et al*., 2017), a threatening pathologic feature that accompanies dysregulated immune responses to ionizing radiation as well as to mobile telecommunication electromagnetic fields (Koca *et al*., 2014). Co-culturing Arthrospira platensis with the probiotic blend in the same aqueous medium allows exchange of biological information through horizontal gene transfer and quantum entanglement as specifically demonstrated for protective responses to radiations (Mothersill *et al*., 2018). The transfer of information described above is based on the homologies of amino acid sequence and function of the genes belonging to the family of *uvr* since the proteins coded for by *uvr* genes of Arthospira platensis and Lactococcus lactis subsp. lactis, one of the strains of the probiotic blend, share significant homologies that are responsible for the transfer of information. Transfer of information to human cells occurs through an intermediary that is constituted by Lactococcus phage ul36 (Ruggiero, 2020).

Rationale for the use of Equisetum Arvense

Equisetum arvense (field horsetail) is a perennial plant from the family of Equisetaceae. Flavonoids, phenolic acids, alkaloids, phytosterols, tannins and triterpenoids are among the most widely known phytochemical compounds of Equisetum arvense. Several studies described different health promoting properties of Equisetum arvense such as anti-oxidant, anti-inflammatory, anti-bacterial, anti-fungal, blood vessel relaxant, neuro-and cardio-protective and anti-proliferative properties (Pallag *et al*., 2018). The anti-cancer properties of Equisetum arvense are so well documented that an article published in 2020 states *"[Equisetum arvense] may serve as an alternative anticancer agent for the treatment of pancreatic carcinoma with no or least side effects to the patient*" (Bhat *et al*., 2020). Also the anti-inflammatory properties of the plant are well documented and the mechanism of action for the anti-inflammatory effect is based on modulation of interleukins and interferon (Steinborn *et al*., 2018). The rationale for using Equisetum arvense in the co-culture described above is based on two properties of the plant. 1. Its anti-oxidant properties that counteract oxidative stress caused by radiations, thus synergizing with Arthrospira platensis and with phages of the probiotic blend resulting in inhibition of excessive reactive oxygen species formation 2. The high content of silica that is arranged in surface fractals in the stem and leaf of Equisetum. Silica from Equisetum arvense plays a fundamental role in the co-culture as it favors horizontal gene transfer between radio-resistant Arthrospira platensis and the microbes of the probiotic blend. A number of studies demonstrated that adsorption to minerals, such as silica and silicates, increases DNA longevity and stability in the environment. Such DNA-mineral associations can favor preserving genetic information across time, an essential feature in the context of an approach designed to withstand the noxious effects of radiations. In addition, DNA associated with silica is available for incorporation into organisms different from those where DNA originated through the process of horizontal gene transfer. The complex silica-DNA holds the potential for transferring genetic material across environments and timescales to distant organisms up to the point that it has been hypothesizes that this process has significantly influenced the evolution of life on Earth (Sand and Jelavić, 2018). Interestingly, Equisetum is considered a "living fossil", since it is the only living genus of the entire subclass Equisetidae, a class that was widely represented in the late Paleozoic forests and survived the largest extinction event in the history of Earth, the Permian-Triassic extinction event. In the context of the co-culture, Equisetum arvense serves the purpose of reproducing the conditions that are believed to be present at the beginning of the life on Earth, when nucleic acids bound to minerals such as silica and silicates and were thus able to maintain, transfer and propagate the primeval biological information. More precisely, silica favors exchange of information between radio-resistant Arthrospira platensis and the microbes of the probiotic blend. This optimization of the exchange of biological information mediated by silica occurs at the classical biochemical level through horizontal gene transfer and may also occur at the quantum level. About this latter concept, it was demonstrated that DNA self-assembles in network structures on silica surfaces in such a way that it can be used for quantum computation (Xiao *et al*., 2002) and it was also demonstrated that quantum entanglement synchronizes DNA strand breakage across relatively large distances by enzymes that recognize specific sequences. Such a quantum entanglement, that in the case of the co-culture is amplified by silica, explains the observed persistent effects of enzymes that interact with DNA across longer spatial separations, a phenomenon that cannot be explained in terms of classical biochemistry (Kurian *et al*., 2016). In addition, silica serves the purpose of absorbing phages, thereby enhancing their effectiveness in transferring the information to other microbes as well as to human cells. It was demonstrated that phages are active while adsorbed on the surface of silica particles and the number of active phages bound to the silica is enhanced by the presence of ionic surfaces, with greater surface charge correlating with greater concentration of adsorbed phages (Cademartiri *et al*., 2010). In the co-culture, the ionic surfaces are represented by the phenolic acids of Equisetum arvense and the simultaneous presence of silica and phenolic acids leads to synergism as far as phage absorption is concerned.

Conclusion

The results presented in this study lay the foundation for the development of a novel approach to protection against electromagnetic fields comprising ionizing and non-ionizing radiations. *In silico* observations and preliminary results on subjects exposed to common electromagnetic fields under real-life conditions, support the hypothesis that co-cultures of radiation-resistant cyanobacteria and probiotics in naturally radioactive carbonated mineral water may confer protection against the harmful effects of electromagnetic fields.

Acknowledgement

The Author wishes to thank the Colleagues at Silver Spring Sagl, Switzerland, for their continuous support and encouragement and for sharing scientific information.

Disclosures

Marco Ruggiero is the founder of Silver Spring Sagl, a company producing supplements and probiotics including some of those mentioned in this article and served as CEO of the company until his retirement in 2020. Marco Ruggiero is member of the Editorial Board of the American Journal of Immunology and is waived from the Article Processing fee for this contribution; he receives no remuneration for his editorial work.

Advisory

No information in this study is intended or implied to be a substitute for professional medical advice, diagnosis or treatment.

Ethics

This article is original and contains material that has not been submitted or published in any scientific journal. The concepts and some of the results presented in this article are part of a patent application to the United States Patent and Trademark Office filed in June 2020. A pre-print of the first submission of this article had been posted in bioRxiv (https://doi.org/10.1101/2020.07.21.214676). The current article, however, after thorough revision following the Reviewers' comments, is significantly different from the pre-print.

References

Antonucci, N., Pacini, S., & Ruggiero, M. (2019). Use of an extremely biodiverse probiotic and a supplement based on microbial chondroitin sulfate is associated with a significant decrease of serum free kappa light chains as well as a trend toward normalization of kappa/lambda ratio and of plasma cell bone marrow infiltration in a case of multiple myeloma. American Journal of Immunology, 15, 5-9. https://doi.org/10.3844/ajisp.2019.5.9

Badri, H., Monsieurs, P., Coninx, I., Wattiez, R., & Leys, N. (2015). Molecular investigation of the radiation resistance of edible cyanobacterium Arthrospira sp. PCC 8005. Microbiology Open, 4(2), 187-207. https://doi.org/10.1002/mbo3.229

Beres, S., Nemeth, A., Ajtay, Z., Kiss, I., Nemeth, B., & Hejjel, L. (2018). Cellular phone irradiation of the head affects heart rate variability depending on Inspiration/Expiration ratio. In Vivo, 32(5), 1145-1153. https://doi.org/10.21873/invivo.11357

Bhat, A. A., Ahamad, B., Rehman, M. U., & Ahmad, P. (2020). Impact of ethanolic extract of Equisetum arvense (EA1) on pancreatic carcinoma AsPC-1 cells. Saudi Journal of Biological Sciences, 27(5), 1260-1264. https://doi.org/10.1016/j.sjbs.2020.01.029

Bhat, V. B., & Madyastha, K. M. (2001). Scavenging of peroxynitrite by phycocyanin and phycocyanobilin from Spirulina platensis: protection against oxidative damage to DNA. Biochemical and Biophysical Research Communications, 285(2), 262-266. https://doi.org/10.1006/bbrc.2001.5195

Blythe, J., Ruggiero, M., & Pacini, S. (2017). Intermittent fasting and probiotic yogurt consumption are associated with reduction of serum alpha-N-acetylgalactosaminidase and increased urinary excretion of lipohilic toxicants. Madridge Journal Immunology, 1(1), 23-27. https://doi.org/10.18689/mjim-1000107

Bradstreet, J. J., Pacini, S., & Ruggiero, M. (2014). A new methodology of viewing extra-axial fluid and cortical abnormalities in children with autism via transcranial ultrasonography. Frontiers in Human Neuroscience, 7, 934. https://doi.org/10.3389/fnhum.2013.00934. PMID: 24459462; PMCID: PMC3892177.

Branca, J. J. V., Pacini, S., Morucci, G., Bocchi, L., Cosentino, A., Boni, E., & Ruggiero, M. (2018). Effects of ultrasound and selenium on human neurons in vitro. Archives Italiennes de Biologie, 156(4), 153-163. https://doi.org/10.12871/00039829201842

Brookes, J. C. (2017). Quantum effects in biology: golden rule in enzymes, olfaction, photosynthesis and magnetodetection. Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences, 473(2201), 20160822. https://doi.org/10.1098/rspa.2016.0822

Cademartiri, R., Anany, H., Gross, I., Bhayani, R., Griffiths, M., & Brook, M. A. (2010). Immobilization of bacteriophages on modified silica particles. Biomaterials, 31(7), 1904-1910. https://doi.org/10.1016/j.biomaterials.2009.11.029

Carter, M., Pacini, S., & Ruggiero, M. (2020). Consumption of an Extremely Biodiverse Probiotic and a Supplement based on Microbial Chondroitin Sulfate is Associated with Very Low Serum Alpha-N-acetylgalactosaminidase (Nagalase) Activity and Decrease of C-reactive Protein Values. American Journal of Immunology, 16, 8-18. https://doi.org/10.3844/ajisp.2020.8.18

Casamassima, F., Pacini, S., Panichi, M., Milano, F., Pinzani, P., Pazzagli, M., & Ruggiero, M. (1999). Nucleoside analogues as radiosensitizers in the treatment of lung cancer. In: Roda, A., Pazzagli, M., Kricka L. J., & Stanley, P. E. Eds.), Bioluminescence and chemiluminescence: Perspectives for the 21st century, (pp. 551-554), John Wiley and Sons, Chichester, U.K., ISBN-10: 0471987336.

Casamassima, F., Ruggiero, C., Caramella, D., Tinacci, E., Villari, N., & Ruggiero, M. (1989). Hematopoietic bone marrow recovery after radiation therapy: MRI evaluation. Blood, 73(6), 1677-1681. https://doi.org/10.1182/blood.V73.6.1677.1677

Chiarugi, V., Magnelli, L., Cinelli, M., Turchetti, A., & Ruggiero, M. (1995). Dominant oncogenes, tumor suppressors and radio sensitivity. Cellular & Molecular Biology Research, 41(3), 161-166. https://europepmc.org/article/med/8589756

Crabtree, D. P., Herrera, B. J., & Kang, S. (2017). The response of human bacteria to static magnetic field and radiofrequency electromagnetic field. Journal of Microbiology, 55(10), 809-815. https://doi.org/10.1007/s12275-017-7208-7

Drury, R. L., Porges, S., Thayer, J., & Ginsberg, J. P. (2019). Heart rate variability, health and well-being: A systems perspective. Frontiers in Public Health, 7, 323. https://doi.org/10.3389/fpubh.2019.00323

Fleckenstein, J., & Schnug, E. (2001). Issues of uranium and radioactivity in natural mineral waters. Landbauforschung Volkenrode, 51(4), 149-157. https://literatur.thuenen.de/digbib_extern/zi028306.pdf

Górski, A., Jończyk-Matysiak, E., Łusiak-Szelachowska, M., Międzybrodzki, R., Weber-Dąbrowska, B., & Borysowski, J. (2017). The potential of phage therapy in sepsis. Frontiers in Immunology, 8, 1783. https://doi.org/10.3389/fimmu.2017.01783

Gupta, S., Gupta, C., Garg, A. P., & Prakash, D. (2017). Prebiotic efficiency of blue green algae on probiotics microorganisms. Journal of Microbiology and Experimentation, 4(4), 1-4. https://doi.org/10.15406/jmen.2017.04.00120

IARC. (2002). IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, World Health Organization, & International Agency for Research on Cancer. Non-ionizing Radiation: Static and extremely low-frequency (ELF) electric and magnetic fields. https://www.ncbi.nlm.nih.gov/books/NBK390731/

Johansson, O. (2009). Disturbance of the immune system by electromagnetic fields-A potentially underlying cause for cellular damage and tissue repair reduction which could lead to disease and impairment. Pathophysiology, 16(2-3), 157-177. https://doi.org/10.1016/j.pathophys.2009.03.004

Karkos, P. D., Leong, S. C., Karkos, C. D., Sivaji, N., & Assimakopoulos, D. A. (2011). Spirulina in clinical practice: evidence-based human applications. Evidence-based Complementary and Alternative Medicine, 2011, 531053. https://doi.org/10.1093/ecam/nen058

Kesari, K. K., Kumar, S., & Behari, J. (2011). 900-MHz microwave radiation promotes oxidation in rat brain. Electromagnetic Biology and Medicine, 30(4), 219-234. https://doi.org/10.3109/15368378.2011.587930

Klinghardt, D. (2017). The Ruggiero-Klinghardt (RK) protocol for the diagnosis and treatment of chronic conditions with particular focus on Lyme disease. American Journal of Immunology, 13(2), 114-126. https://doi.org/10.3844/ajisp.2017.114.126

Koca, O., Gokce, A. M., Akyuz, M., Ercan, F., Yurdakul, N., & Karaman, M. I. (2014). A new problem in inflammatory bladder diseases: Use of mobile phones!. International BrazJurol, 40(4), 520-525. https://doi.org/10.1590/S1677-5538.IBJU.2014.04.11

Kostoff, R. N., Heroux, P., Aschner, M., & Tsatsakis, A. (2020). Adverse health effects of 5G mobile networking technology under real-life conditions. Toxicology Letters, 323, 35-40. https://doi.org/10.1016/j.toxlet.2020.01.020

Kovalenko, V. F., Levchenko, P. G., Shutov, S. V., & Bordiuk, A. Y. (2009). Investigation of the nature of light scattering by water. Ukrainian Journal of Physical Optics, 10(1), 38-53. http://www.ifo.lviv.ua/journal/UJPO_PDF/2009_1/0301_2009.pdf

Kurian, P., Dunston, G., & Lindesay, J. (2016). How quantum entanglement in DNA synchronizes double-strand breakage by type II restriction endonucleases. Journal of Theoretical Biology, 391, 102-112. https://doi.org/10.1016/j.jtbi.2015.11.018

Levin, S. G., Young, R. W., & Stohler, R. L. (1992). Estimation of median human lethal radiation dose computed from data on occupants of reinforced concrete structures in Nagasaki, Japan. Health Physics, 63(5), 522-531. https://doi.org/10.1097/00004032-199211000-00003

López-Furelos, A., Salas-Sánchez, A. A., Ares-Pena, F. J., Leiro-Vidal, J. M., & López-Martín, E. (2018). Exposure to radiation from single or combined radio frequencies provokes macrophage dysfunction in the RAW 264.7 cell line. International Journal of Radiation Biology, 94(6), 607-618. https://doi.org/10.1080/09553002.2018.1465610

Lu, Y. S., Huang, B. T., & Huang, Y. X. (2012). Reactive oxygen species formation and apoptosis in human peripheral blood mononuclear cell induced by 900 MHz mobile phone radiation. Oxidative Medicine and Cellular Longevity, 2012. https://doi.org/10.1155/2012/740280

Marletto, C., Coles, D. M., Farrow, T., & Vedral, V. (2018). Entanglement between living bacteria and quantized light witnessed by Rabi splitting. Journal of Physics Communications, 2(10), 101001. https://doi.org/10.1088/2399-6528/aae224

Mazo, V. K., Gmoshinskiĭ, I. V., Sokolova, A. G., Zorin, S. N., Danilina, L. L., Litvinova, A. V., & Radchenko, S. N. (1999). Effect of biologically active food additives containing autolysate of baker's yeast and spirulina on intestinal permeability in an experiment. VoprosyPitaniia, 68(1), 17-19. https://europepmc.org/article/med/10198958

Mazzanti, R., Fantappie, O., Fabrizio, P., Pacini, S., Relli, P., Casamassima, F., ... & Ruggiero, M. (1996). Conferring drug resistance by MDR1 gene transfection increases susceptibility to irradiation and lipid peroxidation in 3T3 cell line. Free Radical Biology and Medicine, 20(4), 601-606. https://doi.org/10.1016/0891-5849(95)02063-2

Mihai, C. T., Rotinberg, P., Brinza, F., & Vochita, G. (2014). Extremely low-frequency electromagnetic fields cause DNA strand breaks in normal cells. Journal of Environmental Health Science and Engineering, 12(1), 1-7. http://www.ifo.lviv.ua/journal/UJPO_PDF/2009_1/0301_2009.pdf

Mothersill, C., Smith, R., Wang, J., Rusin, A., Fernandez-Palomo, C., Fazzari, J., & Seymour, C. (2018). Biological entanglement–like effect after communication of fish prior to X-ray exposure. Dose-Response, 16(1), 1559325817750067. https://doi.org/10.1177/1559325817750067

Orlandini, G. E., Ruggiero, L., Gulisano, M., Ruggiero, M., Villari, N., & Casamassima, F. (1991). Magnetic resonance (MR) evaluation of bone marrow in vertebral bodies. Archivioitaliano di anatomia e di embriologia. Italian Journal of Anatomy and Embryology, 96(2), 93-100. https://europepmc.org/article/med/1805708

Pacini, S., & Ruggiero, M. (2019a). Natural Plasmids in a Swiss Fermented Milk and Colostrum Product assessed by Microbiome Array. Madridge Journal Immunology, 3(2), 100-108. https://doi.org/10.18689/mjim-1000123

Pacini, S., & Ruggiero, M. (2019b). Phage composition of a fermented milk and colostrum product assessed by microbiome array; putative role of open reading frames. bioRxiv, 714154. https://doi.org/10.15406/jnsk.2020.10.00416

Pacini, S., Gulisano, M., Peruzzi, B., Sgambati, E., Gheri, G., Bryk, S. G., ... & Ruggiero, M. (2003). Effects of 0.2 T static magnetic field on human skin fibroblasts. Cancer Detection and Prevention, 27(5), 327-332. https://doi.org/10.1016/s0361-090x(03)00124-7

Pacini, S., Milano, F., Pinzani, P., Pazzagli, M., Gulisano, M., Ruggiero, M., & Casamassima, F. (1999a). Effects of Gemcitabine in Normaland Transformed Human Lung Cell Cultures: Cytotoxicity and Increase in Radiation Sensitivity. Tumori Journal, 85(6), 503-507. https://doi.org/10.1177/030089169908500615

Pacini, S., Vannelli, G. B., Barni, T., Ruggiero, M., Sardi, I., Pacini, P., & Gulisano, M. (1999b). Effect of 0.2 T static magnetic field on human neurons: remodeling and inhibition of signal transduction without genome instability. Neuroscience Letters, 267(3), 185-188. https://doi.org/10.1016/s0304-3940(99)00362-6

Pacini, S., Aterini, S., Pacini, P., Ruggiero, C., Gulisano, M., & Ruggiero, M. (1999c). Influence of static magnetic field on the antiproliferative effects of vitamin D on human breast cancer cells. Oncology Research Featuring Preclinical and Clinical Cancer Therapeutics, 11(6), 265-271. https://www.ingentaconnect.com/content/cog/or/1999/00000011/00000006/art00003

Pacini, S., Morucci, G., Punzi, T., Gulisano, M., Ruggiero, M., Amato, M., & Aterini, S. (2012). Effect of paricalcitol and GcMAF on angiogenesis and human peripheral blood mononuclear cell proliferation and signaling. Journal of Nephrology, 25(4), 577. https://doi.org/10.5301/jn.5000035

Pacini, S., Punzi, T., Gulisano, M., Cecchi, F., Vannucchi, S., & Ruggiero, M. (2006). Transdermal delivery of heparin using pulsed current iontophoresis. Pharmaceutical Research, 23(1), 114-120. https://doi.org/10.1007/s11095-005-8923-z

Pacini, S., Ruggiero, M., Casamassima, F., Santucci, M. A., Milano, F., Ranaldi, F., ... & Giachetti, E. (1995). Study of second messenger levels and of sugar catabolism enzyme activities in transformed cells resistant to ionizing radiations. Biochemistry and Molecular Biology International, 37(1), 81-88. https://europepmc.org/article/med/8653091

Pacini, S., Ruggiero, M., Sardi, I., Aterini, S., Gulisano, F., & Gulisano, M. (2002). Exposure to global system for mobile communication (GSM) cellular phone radiofrequency alters gene expression, proliferation and morphology of human skin fibroblasts. Oncology Research Featuring Preclinical and Clinical Cancer Therapeutics, 13(1), 19-24. https://doi.org/10.3727/096504002108747926

Pacini, S., Vincenzini, M. T., Marraccini, P., Iantomasi, T., Santucci, M. A., Casamassima, F., & Ruggiero, M. (1994a). Molecular mechanisms responsible for radio resistance in cells transformed by oncogenes involved in lung cancer. In: Motta, G. (Ed.), Lung Cancer: Frontiers in Science and Treatment, (pp. 195-200), L.P. Graf. Publisher, ISBN-10: 8890001518.

Pacini, S., Santucci, M. A., Milano, F., Casamassima, F., Greenberger, J. S., Pierce, J. H., & Ruggiero, M. (1994b). Increased formation of diacylglycerol in tumor cells that are resistant to ionizing radiations. Radiation Oncology Investigations, 2(1), 20-24. https://doi.org/10.1002/roi.2970020104

Pallag, A., Filip, G. A., Olteanu, D., Clichici, S., Baldea, I., Jurca, T., ... & Mureşan, M. (2018). Equisetum arvense L. extract induces antibacterial activity and modulates oxidative stress, inflammation and apoptosis in endothelial vascular cells exposed to hyperosmotic stress. Oxidative Medicine and Cellular Longevity, 2018, 3060525. https://doi.org/10.1155/2018/3060525

Puértolas-Balint, F., & Schroeder, B. O. (2020). Does an Apple a Day Also Keep the Microbes Away? The Interplay Between Diet, Microbiota and Host Defense Peptides at the Intestinal Mucosal Barrier. Frontiers in Immunology, 11, 1164. https://doi.org/10.3389/fimmu.2020.01164

Qishen, P., Baojiang, G., & Kolman, A. (1989). Radioprotective effect of extract from Spirulina platensis in mouse bone marrow cells studied by using the micronucleus test. Toxicology Letters, 48(2), 165-169. https://doi.org/10.1016/0378-4274(89)90171-9

Ran, C., Zhang, Z., Hooker, J., & Moore, A. (2012). In vivo photo activation without "light": use of Cherenkov radiation to overcome the penetration limit of light. Molecular Imaging and Biology, 14(2), 156-162. http://dx.doi.org/10.1007/s11307-011-0489-z

Ruggiero, M. (2008). Static magnetic fields, blood and genes: an intriguing relationship. Cancer Biology & Therapy, 7(6), 820-821. https://doi.org/10.4161/cbt.7.6.6299

Ruggiero, M. (2020). Experimental evidence for the role of natural radioactivity in influencing viability of commensal microorganisms. bioRxiv. https://doi.org/10.1101/2020.07.21.214676

Ruggiero, M., & Aterini, S. (2015). Electromagnetic Fields. In: Schwab, M. (Ed.), Encyclopedia of Cancer, Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-27841-9_1843-4

Ruggiero, M., Bottaro, D. P., Liguri, G., Gulisano, M., Peruzzi, B., & Pacini, S. (2004). 0.2 T magnetic field inhibits angiogenesis in chick embryo chorioallantoic membrane. Bioelectromagnetics: Journal of the Bioelectromagnetics Society, The Society for Physical Regulation in Biology and Medicine, The European Bioelectromagnetics Association, 25(5), 390-396. https://doi.org/10.1002/bem.20008

Ruggiero, M., Casamassima, F., Magnelli, L., Pacini, S., Pierce, J. H., Greenberger, J. S., & Chiarugi, V. P. (1992). Mitogenic signal transduction: a common target for oncogenes that induce resistance to ionizing radiations. Biochemical and Biophysical Research Communications, 183(2), 652-658. https://doi.org/10.1016/0006-291x(92)90532-p

Ruggiero, M., Magherini, S., Fiore, M. G., Chiarelli, B., & Morucci, G. (2013). Transcranial sonography: A technique for the study of the temporal lobes of the human and non-human primate brain. Italian Journal of Anatomy and Embryology, 118(3), 241-55. https://www.torrossa.com/en/resources/an/3006643

Sand, K. K., & Jelavić, S. (2018). Mineral facilitated horizontal gene transfer: A new principle for evolution of life?. Frontiers in Microbiology, 9, 2217. https://doi.org/10.3389/fmicb.2018.02217

Santucci, M. A., Greenberger, J. S., Pierce, J. H., Babini, L., Barbieri, E., Pacini, S., ... & Ruggiero, M. (1996). Overexpression of a synthetic phosphotyrosine protein phosphatase gene increases radiosensitivity in vitro of normal and transformed murine NIH/3T3 fibroblasts. Radiation Oncology Investigations: Clinical and Basic Research, 4(1), 1-8. https://doi.org/10.1002/(SICI)1520-6823(1996)4:1<1::AID-ROI1>3.0.CO;2-1

Simkó, M., & Mattsson, M. O. (2019). 5G wireless communication and health effects-a pragmatic review based on available studies regarding 6 to 100 GHz. International Journal of Environmental Research and Public Health, 16(18), 3406. https://doi.org/10.3390/ijerph16183406

Steinborn, C., Potterat, O., Meyer, U., Trittler, R., Stadlbauer, S., Huber, R., & Gründemann, C. (2018). In vitro anti-inflammatory effects of equisetum arvense are not solely mediated by silica. Planta Medica, 50(08), 519-526. https://doi.org/10.1055/s-0043-123075

UniProt Consortium. (2019). UniProt: a worldwide hub of protein knowledge. Nucleic Acids Research, 47(D1), D506-D515. https://doi.org/10.1093/nar/gky1049

Van Belleghem, J. D., Dąbrowska, K., Vaneechoutte, M., Barr, J. J., & Bollyky, P. L. (2019). Interactions between bacteriophage, bacteria and the mammalian immune system. Viruses, 11(1), 10. https://doi.org/10.3390/v11010010

Vincenzini, M. T., Marraccini, P., Iantomasi, T., Favilli, F., Pacini, S., & Ruggiero, M. (1993). Altered metabolism of glutathione in cells transformed by oncogenes which cause resistance to ionizing radiations. FEBS Letters, 320(3), 219-223. https://doi.org/10.1016/0014-5793(93)80590-q

Wallace, T. C., Guarner, F., Madsen, K., Cabana, M. D., Gibson, G., Hentges, E., & Sanders, M. E. (2011). Human gut microbiota and its relationship to health and disease. Nutrition Reviews, 69(7), 392-403. https://doi.org/10.1111/j.1753-4887.2011.00402.x

Xiao, Z., Xu, M., Ohgi, T., Sagisaka, K., & Fujita, D. (2002). Controlled assembly of DNA nanostructures on silanized silicon and mica surfaces for future molecular devices. Superlattices and Microstructures, 32(4-6), 215-220. https://doi.org/10.1016/S0749-6036(03)00021-1

Zunaid, I. R., Pacini, S., & Ruggiero, M. (2020). Significance of hydrophobic and charged sequence similarities in sodium-bile acid cotransporter and vitamin D-binding protein macrophage activating factor. bioRxiv. https://doi.org/10.1101/2020.03.03.975524