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# **The role of space weather and geophysical processes in behavioral studies**

## **Review**

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## 20 **Summary**

21 Since the dawn of spaceflight research, scientists have been interested in the  
22 atmospheric, radiative and magnetic effects on living organisms. Animal behavioral  
23 studies also benefit from the latest findings, such as the neuroendocrine aspects of ion  
24 concentration or the connection between earthquake-generated extreme low  
25 frequencies and fight-or-flight responses. This review attempted to gather all aspects  
26 that might play some role in animal – partly human – behavioral reactions.

## 27 **Abstract**

28 Living organisms with developed endocrine systems react in a complex way to  
29 environmental changes. Changing atmospheric pressure causes different blood  
30 pressures or hormone levels; carcinogenic radiation modifies the structure of DNA.  
31 Charged particles and ions act as neurotransmitters and block certain types of protein  
32 channels and receptors. A high concentration of carbon dioxide has an indirect effect  
33 on both blood pressure and neuron activity. The bioelectric nature of living tissues  
34 highlights the complexity of the connection between the dynamic physical environment  
35 and biological systems. Recent results from studies on the interactions and connections  
36 mentioned above are reviewed in this paper.

37 **Keywords:** Gaia theory, biometeorology, magnetism, ions, hormones

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## 42 **Introduction**

43 *“Everything is the product of one universal creative effort. There is nothing dead in*  
44 *Nature. Everything is organic and living, and therefore the whole world appears to be*  
45 *a living organism.” Lucius Annaeus Seneca*

46 Lifeforms on Earth follow the same rules of physics as any nonliving process. Our  
47 intention is to describe recent studies and their results that relate the operation and  
48 behavior of living systems with the physics of the cosmic environment of our planet.  
49 The idea of relating biology and physics has a long history. Efforts have been made to  
50 place biospheric and cosmic interactions into the theory of everything (Cochran, 1971);  
51 even quantum mechanics and biology are on the same stage (Marais et al., 2018). Deep  
52 theoretical physics attempts to find the Rosetta stone of the universe to connect general  
53 relativity with quantum physics and answer questions regarding black holes, black  
54 matter and multidimensions. String theory, based on the latter, anchors to the known  
55 universe with the help of biological structures such as mycelium networks or with  
56 nuclear pasta theory (Berry et al., 2016). Beyond the gloomy and hardly understandable  
57 theories, there are interesting interactions between the biosphere and environment. This  
58 review attempts to gather existing geophysical, biochemical and even genetic research  
59 starting from the cosmic level and going toward biospheric systems.

## 60 *Matrix of elements*

61 Living systems on Earth are exposed to several effects from interactions between solar  
62 activity (Graviou, 1978) and the geomagnetic field, galactic cosmic rays and  
63 electromagnetic phenomena caused by electric activity in the atmosphere. In addition  
64 to the effects mentioned above, piezoelectric phenomena coming from earthquakes can  
65 also affect living systems. Based on several different recent studies (Thornhill &

66 Talbott, 2007; Findlay, 2012), it is reasonable to suppose that the effects in question  
67 have more complex influences on the biosphere than previously thought.

68 Solar corpuscular radiation (solar wind, by its popular name) consisting of protons and  
69 electrons interacts with the geomagnetic field. The latter, due to this interaction, serves  
70 as a shield for the terrestrial life, protecting life forms from those high energy particles  
71 as well as from the high energy nuclei of the galactic cosmic rays. Cosmic particles and  
72 the ionizing spectral range of solar electromagnetic radiation result in intensive  
73 ionization processes in the upper atmosphere in which the air becomes conductive;  
74 namely, a permanently ionized region is produced and is present in the upper part of  
75 the gaseous sphere around the planet, called the ionosphere. The altitude of the  
76 ionosphere's lower boundary is variable and is determined by the intensity of solar  
77 activity. Ions are also present in the lower atmosphere due to ionizing solar and galactic  
78 cosmic particles descending to the lower atmosphere and to ionization from the  
79 radioactive materials included in the air and in the soil. Ions can coagulate on aerosol  
80 particles, producing so-called large ions. The complex system of atmospheric  
81 electricity below the ionosphere operates as a capacitor where, in certain cases,  
82 discharges occur that are controlled by atmospheric thunderstorm activity. Discharges  
83 (lightning strikes) operate as antennas and emit electromagnetic radiation in the range  
84 of radio waves. Since these radio waves propagate in the Earth-ionosphere waveguide  
85 that serves as a resonant cavity, standing waves are produced. Additionally, seismic  
86 activity can contribute to the atmospheric electricity processes with earthquake-  
87 resultant piezoelectric activity.

88 Recent studies (Lovelock & Margulis, 1974; Krumbein & Schellnhuber, 1992  
89 Lovelock, 2009; Halasz et al., 2016) propose that organisms interact with their  
90 inorganic environment to create a self-regulating system that is optimal for their own

91 requirements. A growing number of scientists believe that the link between the self-  
92 regulating biosphere and the atmosphere is a two-way connection. Lovelock (2009)  
93 noted that CO<sub>2</sub> and O<sub>2</sub> concentrations in the atmosphere have changed because of the  
94 appearance of life, regardless of organic activity. Metabolic gases transform the  
95 atmosphere, but this process is intentional; Dawkins (1982) found that all organisms  
96 change their environment to survive. For example, cyanobacteria release a metabolic  
97 toxic byproduct called oxygen. Over time, oxygen accumulated in the atmosphere and  
98 provided a perfect niche for aerobic species. Lovelock (2009) adds that the  
99 accumulating oxygen made possible the emergence of photosynthetic plants, but the O<sub>2</sub>  
100 concentration never exceeded a certain level where spontaneous combustion could have  
101 been a serious threat. In other words, metabolic byproducts affect the environment but  
102 their levels do not reach a limit that would threaten their provider. Lovelock and  
103 Margulis (1974) attempted to define this self-regulating system, and they created the  
104 Gaia theory. They declared that there is a complex, bilateral relation between the  
105 biosphere and the physical environment.

106 Along the Gaia theory, it is obvious that space-weather is one of the main drivers of  
107 atmospheric phenomena, including weather. Solar activity induces different changes in  
108 the upper and lower atmosphere. Studies began, a century ago, to find a closer relation  
109 between solar activity and the biosphere. Alexander Chizhevsky collected data  
110 regarding atmospheric changes since the 1930s (Chizhevsky, 1960). His results were  
111 cornerstones in modern space programs, especially in the field studying the link  
112 between cosmic radiation and living organisms. Later findings have also shown that the  
113 electric charge has an important role in cell division (Cone, 1971; Hart, 1983;  
114 Blackiston, McLaughlin, & Levin, 2009). It has been shown that a healthy body cell's

115 surface is negatively charged, but on cancer cells, the negative potential decreases. With  
116 an additional negative charge (ions), lung cancer can be cured (Cone, 1971).

117 Due to the celestial mechanical properties of the Sun-Earth system, seasons and cloud  
118 formation are indirectly defined (Serrano et al, 2006) on our planet. The Moon's gravity  
119 is responsible for the tides and stabilizes Earth's orbital tilt angle (Ward & Brownlee,  
120 2000).

121 Four fundamental interactions, weak nuclear, strong nuclear, gravitational and  
122 electromagnetic, alter the biosphere. As Völgyesi (2010) suggested, the Sun's gravity  
123 has an influence on every planet's tidal forces, in addition to influencing normal  
124 planetary orbits in the Solar System. According to Völgyesi, the terrestrial gravitational  
125 field is fluctuating, and because of Earth's irregular shape, called a "geoid", organisms  
126 live in different gravitational conditions in, for example, South America than in Europe  
127 (Nickerson et al., 2004).

### 128 *Magnetosphere*

129 Earth's magnetosphere protects organisms (Dartnell, 2011) from powerful cosmic rays  
130 and solar wind. The extent and strength of the magnetosphere depends on the activity  
131 of Earth's molten core (iron and nickel), referred to as the dynamo effect (Völgyesi,  
132 1982). The gravity of the Sun and Moon continuously alters the molten core and the  
133 entire lithosphere.

### 134 *Solar wind, magnetosphere and ionosphere*

135 The magnetosphere is an invisible protective field between the Earth and the Sun.  
136 The ionosphere is the region of the upper atmosphere that is ionized by both the  
137 electromagnetic radiation and corpuscular radiation of the Sun. The ionosphere

138 accumulates from electrons, ionized atoms and gas molecules. The solar wind acts like  
139 a cosmic fan and continuously “blows” the Earth’s magnetosphere; consequently, the  
140 lower boundary of the ionosphere moves downward. Because of the solar wind pressure,  
141 the symmetrical magnetosphere is compressed into an asymmetrical form, creating  
142 lobes called the “magneto-tail”. Each month, the Moon passes through this “magneto-  
143 cone” three days before and three days after the full moon. During this period, the  
144 surface of the Moon is extremely exposed to solar wind, and high-energy, charged  
145 particles (electrons, protons, alpha particles) reach its surface. The impacting particles  
146 kick up the powder-fine lunar dust (regolith), which became a thin, floating layer  
147 because of the low gravity. Charged dust in other planets’ atmospheres has not yet been  
148 detected, so this phenomenon may be unique in our solar system (Horányi et al., 2015;  
149 Stubbs et al., 2011).

#### 150 *Magnetism*

151 Begall et al. (2008) examined ruminating and resting cattle and deer with the help of  
152 satellite images and aerial photographs. They observed that these animals graze parallel  
153 with the magnetic north-south lines. The research was based on satellite imagery  
154 combined with longitudinal vectors ignoring the antero-posterior axis. The animals  
155 were observed on level ground, far from water troughs and human settlements. In the  
156 Northern Hemisphere, westerly winds dominate due to the Coriolis force, while in the  
157 Southern Hemisphere, southeast winds dominate. Therefore, wind does not have a  
158 major impact on animal orientation in the north-south direction. The glare of the sun  
159 may confuse the animals; in these cases, images were removed from the sample. The  
160 low position of the Sun may force the animals to turn away, but the test images were  
161 recorded when the Sun was at a high position (short shadows). Cattle graze against the

162 wind and try to stand perpendicular to the angle of incidence of the sun on cold days  
163 (Olson & Wallander, 2001).

#### 164 *Electromagnetic radiation*

165 Electromagnetic radiation, such as UV radiation, the gamma component of radioactive  
166 radiation and infrared radiation, affects living organisms and their neuroendocrine  
167 systems (Hainsworth & Rivera-Chira, 2007).

168 *UV radiation* is antibacterial and interacts with vitamin formation; additionally, it is a  
169 primary energy source of ionization in the ionosphere.

170 *Ozone (O<sub>3</sub>), nitric oxide (NO), oxide (O<sup>2-</sup>) and carbon dioxide ions (CO<sub>2</sub><sup>+</sup>)* are basic  
171 products of UV bombardment and modify the neurotransmitter reuptake process  
172 (Pfeifer & Sulman, 1969). Because of the high-energy photons of UV radiation, it  
173 deprives a large quantity of neutral molecules and atoms from their electrons. In this  
174 sense, radiation may indirectly affect behavior.

175 *Visible light* affects on/off clock genes at the optic nerve and regulates the circadian  
176 cycle of animals (Nagy, 2010).

#### 177 *Charged particles and behavior*

178 Ionized air is essential for healthy breathing and gene expression (Chizhevsky, 1960;  
179 Soyka, 1977). Ions are charged particles and are thus capable of binding to membrane  
180 proteins. Through a complex process, negatively charged oxygen molecules accelerate  
181 the serotonin reuptake process (Bagdy, 2012; Krueger, R.F., & Smith, 1960), while  
182 positively charged carbon ions inhibit the process. One of the serotonin reuptake  
183 proteins is the serotonin transporter (SERT). This channel protein changes its  
184 conformation when free serotonin, Na<sup>+</sup> or Cl<sup>-</sup> ions bind to it. Normal serotonin transport

185 passes through the body from the synapse via this binding mechanism (Kalueff &  
186 LaPorte, 2010). If this protein "pump" is not working properly, serotonin accumulates  
187 in the synapse and causes behavioral changes. Nelson & Rudnick (1982) found that  
188 serotonin cations and Cl<sup>-</sup> ions enter together into the axon, and the process is  
189 electroneutral. The synaptic serotonin level affects SERT activity and is closely related  
190 to the charge conditions.

191 In the atmosphere, both negative and positive ions are present, but radioactive minerals  
192 and gases (radium, uranium, radon), cosmic rays, lightning, wildfires and high-voltage  
193 power lines modify their concentrations (Cote, 2003; Komov, 2003; Lee, 1993; Serrano,  
194 Reis, Rosa, & Lucio, 2006; Wahlin, 1989). Evaporating water increases the ratio of  
195 negative ions. The latest research suggests that negative environmental impacts directly  
196 promote or inhibit certain recessive gene expressions. For instance, a serotonin  
197 transporter protein (SLC6A4) is frequently expressed due to a stressful lifestyle (Bagdy,  
198 2012). An insufficient concentration of serotonin transport proteins leads to a  
199 depressive mood (Phelps, 2005). External stressors (lack of food, high temperature)  
200 have immediate effects on serotonin transport and significantly determine an animal's  
201 mood and stress tolerance. Adams et al. (2012) noted that warm-blooded animals  
202 produce serotonin from tryptophan in the brain in the presence of stressors. During live  
203 animal transport, serotonin levels increase while tryptophan and cortisol levels remain  
204 unchanged. Ninety percent of serotonin is synthesized and stored in the intestine, and  
205 stress triggers the release of serotonin into the bloodstream. Moya et al., (2013) showed  
206 that beef cattle can be reliably tested for cortisol (from hair samples), which is strongly  
207 dependent on the serotonin level.

208 Bartošová et al., (2012) observed that the eye gland in ruminants opens and closes  
209 depending on the stress level of the ruminant. They concluded that during animal  
210 handling, eye gland activity could be a good indicator of the stress level.

211 Crespi, (2010) explains that serotonin affects microtubular protein synthesis in the  
212 cytoskeleton. His research opens the discussion regarding the effect of decreasing  
213 serotonin on neural plasticity, highlighting that mood regulation is a complex  
214 neuroendocrine physiological process.

#### 215 *Infrasound waves, piezoelectricity and Schumann resonance*

216 Seismic activity provides extremely low-frequency (ELF) electromagnetic (EM)  
217 radiation (Schumann resonances 0-45 Hz) in the forms of piezoelectricity and  
218 infrasound.

219 Prof. Ikeya (Ikeya et al., 1997) introduced an electromagnetic (EM) model that might  
220 describe the relation between piezoelectric-induced ELF EM and atmospheric  
221 disturbances (earthquake clouds). Based on the research of Rikitake (1994), Hayakawa  
222 (2013) confirmed that ELF EM prior to earthquakes played a primary role in abnormal  
223 animal behavior, especially in small mammals (rats, mice, hamsters) and lizards.

224 Cherry (2003) stated that geomagnetic and solar activities are correlated with serotonin  
225 and melatonin levels. The evidence relates to a comparison of the optimum melatonin  
226 level and the mean Schumann resonance signal strength. The human brain has  
227 developed an ELF oscillating ion system, primarily using calcium ions, to control  
228 neurotransmitters (Adey, 1990). It is well established (Blackman, 1990) that external  
229 electromagnetic ELF signals induce altered neuron calcium ion effluxes in brain tissue.

230 All the above correlations suggest that piezo-induced EM radiation has biological  
231 effects (Reed et al., 1993).

### 232 *Epigenetics*

233 The latest epigenetic studies suggest that negative environmental effects directly  
234 promote or inhibit the expression of certain protein variants. The short transcript variant  
235 of the serotonin transporter protein coding gene (SLC6A4) is expressed more often as  
236 a result of a stressful lifestyle (Bagdy, 2012). Insufficient concentrations of the  
237 serotonin transporter protein cause synaptic fatigue or depression, which then lead to  
238 agitated behavior (Phelps, 2005).

### 239 *CO<sub>2</sub> and radon*

240 Beyond the effects of charged particles, the latest research (Pavlik, 1967) has  
241 discovered new pathways to biometeorological interactions (Juutilainen & Lahtinen,  
242 1985). For instance, radioactive radon gas and atmospheric CO<sub>2</sub> have vasodilation  
243 effects on veins (MD. Nagy, 2008). This process takes place in smooth muscle cells  
244 within vessel walls, and there is a positive correlation between CO<sub>2</sub> concentration and  
245 vascular resistance. Recent research (Fathi et al., 2011) found that CO<sub>2</sub> has a similar  
246 mechanism of action to nitric oxide (NO) as a cardiovascular signaling molecule.

### 247 **Conclusion**

248 Recent studies have allowed for a deeper understanding of molecular interactions,  
249 membrane transport, and even protein synthesis based on fundamental laws of physics.  
250 Studies based on empirical experiments have proven that animals (especially soil  
251 dwellers) are able to detect specific precursors of earthquakes. We do not understand  
252 the whole biophysical process behind this result, but the inclusion of animal behavior

253 is common in earthquake prediction models. Magnetism-influenced behavior is also  
254 observed. Understanding the mechanism of magnetism-influenced behavior at the  
255 biophysical level could be useful in animal housing, ecological observations or human  
256 medical research. Interactions between fields, atoms and complex living tissues suggest  
257 that we need to train our thinking, from time to time, as:

258 “*Science is a way of thinking much more than it is a body of knowledge.*” Carl Sagan

### 259 **Conflict of Interest**

260 On behalf of all authors, the corresponding author states that there is no conflict of  
261 interest.

### 262 **References**

263 Adams, A. L., Friend, T. H., Holub, G. A., Berghman, L. R., Riggs, P. K., Garey, S.  
264 M., Terrill, C. L. and Carter, M. J. (2012). Stress affects plasma serotonin, but  
265 not tryptophan, in Holstein steer calves. *Journal of Animal Science*, 90  
266 (Supplement 3), 253.

267 Adey, W. R. (1990). Electromagnetic fields and the essence of living systems. In J. B.  
268 Anderson (Ed.), *Modern Radio Science*. (pp. 1-37.). Oxford.

269 Bagdy, G. (2012). Génjeink és a lelki egészség. A stressz hatásának és a depresszió  
270 genomikájának összefüggései és tanulságai. *Magyar Tudomány*, 2012(6), 660-  
271 672.

272 Bartošová, J., Ceacero, F., & Bartoš, L. (2012). Pre-orbital gland opening: part of  
273 sucking behavior in red deer (*Cervus elaphus*) calves. *Journal of Animal Science*,  
274 90(9), 3207–3212. <https://doi.org/10.2527/jas.2011-4393>

- 275 Begall, S., Cervený, J., Neef, J., Vojtech, O., & Burda, H. (2008). Magnetic alignment  
276 in grazing and resting cattle and deer. *Proceedings of the National Academy of*  
277 *Sciences*, 105(36), 13451–13455. <https://doi.org/10.1073/pnas.0803650105>
- 278 Berry, D. K., Caplan, M. E., Horowitz, C. J., Huber, G., & Schneider, A. S. (2016).  
279 “Parking-garage” structures in nuclear astrophysics and cellular biophysics.  
280 *Physical Review C*, 94(5), 055801. <https://doi.org/10.1103/PhysRevC.94.055801>
- 281 Blackiston, D. J., McLaughlin, K. a., & Levin, M. (2009). Bioelectric controls of cell  
282 proliferation: ion channels, membrane voltage and the cell cycle. *Cell Cycle*  
283 *(Georgetown, Tex.)*, 8(21), 3519–3528. <https://doi.org/10.4161/cc.8.21.9888>
- 284 Blackman, C. F. (1990). ELF effects on calcium homeostasis. In B. W. Wilson, R. G.  
285 Stevens, & L. E. Anderson (Eds.), *Extremely low frequency electromagnetic*  
286 *fields: The question of cancer*. (pp. 187-208.). Columbus: Publ. Battelle Press.
- 287 Cherry, N. J. (2003). Human intelligence: The brain, an electromagnetic system  
288 synchronised by the Schumann Resonance signal. *Medical Hypotheses*, 60(6),  
289 843–844. [https://doi.org/10.1016/S0306-9877\(03\)00027-6](https://doi.org/10.1016/S0306-9877(03)00027-6)
- 290 Chizhevsky, A. L. (1960). *Air Ionization: Its Role in the National Economy*.  
291 *Аэроионификация в народном хозяйстве*. Moscow.
- 292 Cochran, A. A. (1971). Relationships between quantum physics and biology.  
293 *Foundations of Physics*, 1(3), 235–250. <https://doi.org/10.1007/BF00708610>
- 294 Cone, C. D. J. (1971). Unified theory on the basic mechanism of normal mitotic  
295 control and oncogenesis. *Journal of Theoretical Biology*, 30, 151–181.
- 296 Cote, J. Y. (2003). *The ion miracle*. Francois Lepine.

- 297 Crespi, F. (2010). Further Electrochemical and Behavioural Evidence of a Direct  
298 Relationship Between Central 5-HT and Cytoskeleton in the Control of Mood.  
299 *The Open Neurology Journal*, 4, 5–14.  
300 <https://doi.org/10.2174/1874205X01004010005>
- 301 Dartnell, L. R. (2011). Ionizing radiation and life. *Astrobiology*, 11(6), 551–582.  
302 <https://doi.org/10.1089/ast.2010.0528>
- 303 Dawkins, R. (1982). *The Extended Phenotype*. Gondolat Kiadó, 1989.
- 304 Fathi, A. R., Yang, C., Bakhtian, K. D., Qi, M., Lonser, R. R., & Pluta, R. M. (2011).  
305 Carbon dioxide influence on nitric oxide production in endothelial cells and  
306 astrocytes: Cellular mechanisms. *Brain Research*, 50–57.  
307 <https://doi.org/10.1016/j.brainres.2011.02.066>.Carbon
- 308 Findlay, T. (2012). *A Beginner's view of our Electric Universe*.  
309 Grosvenor House Publishing LTD. ISBN-101781481415  
310 [https://newtoeu.com/files/A\\_Beginners\\_View\\_of\\_Our\\_Electric\\_Universe-Free.pdf](https://newtoeu.com/files/A_Beginners_View_of_Our_Electric_Universe-Free.pdf)
- 311 Graviou, E. (1978). Analogies between rhythms in plant material, in atmospheric  
312 pressure, and solar lunar periodicities. *International Journal of Biometeorology*  
313 22, 103–111. <https://doi.org/10.1007/BF01552889>
- 314 Hainsworth, R. D., & Rivera-Chira M.J., M. (2007). The autonomic nervous system at  
315 high altitude. *Clinical Autonomic Research*, 17, 13-19.
- 316 Hart, F.X. (1983). Changes in the dielectric properties of a plant stem produced by the  
317 application of voltage steps. *International Journal of Biometeorology* 27, 29–40.  
318 <https://doi.org/10.1007/BF02186298>

- 319 Hayakawa, M. (2013). Possible electromagnetic effects on abnormal animal behavior  
320 before an earthquake. *Animals*, 3(1), 19–32. <https://doi.org/10.3390/ani3010019>
- 321 Horányi, M., Szalay, J. R., Kempf, S., Schmidt, J., Grün, E., Srama, R., &  
322 Sternovsky, Z. (2015). A permanent, asymmetric dust cloud around the Moon.  
323 *Nature*, 522(7556), 324–326. <https://doi.org/10.1038/nature14479>
- 324 Ikeya, M. (2004). *Earthquakes and Animals*. World Scientific Publishing Co. Pte. Ltd.
- 325 Ikeya, M., Sasaoka, H., Teramoto, K., & Huang, C. (1997). Ferroelectric alignment of  
326 piezo compensating charges and tornado.pdf. *Ionics*, 12, 3–11.
- 327 Juutilainen, J., Lahtinen, T. (1985). Effects of low frequency electric fields on the  
328 sedimentation rate of human blood. Preliminary observations. *Int Journal of*  
329 *Biometeorology* 29, 243–252. <https://doi.org/10.1007/BF02189656>
- 330 Kalueff, A., & LaPorte, J. (2010). *Experimental models in serotonin transporter*  
331 *research*. (A. V. Kalueff & J. L. LaPorte, Eds.). Cambridge University Press.
- 332 Komov, I. L. (2003). Monitoring of Radon in Ukraine. In *International Radon*  
333 *Symposium. Volume II*. American Association of Radon Scientists and  
334 Technologists, Inc. October 5-8, 2003.
- 335 Krueger, A. P. S., R.F., & Smith, R. F. (1960). The Biological Mechanisms of Air Ion  
336 Action. *The Journal of General Physiology*, 43(638), 533–540.
- 337 Retrieved from:  
338 <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2195018&tool=pmcentrez&rendertype=abstract>
- 339 Krumbein, W.E. & Schellhuber H. J. (1992). Geophysiology of mineral deposits - a  
340 model for biological driving force of global changes through Earth history. *Terra*  
341 *Nova*, 4, Global Change Special Issue, 351-362.

- 342 Lee, W. B. (1993). About air ions.  
343 Retrieved from: <https://www.trifield.com/content/about-air-ions/>
- 344 Lovelock, J. E. (2009). *The vanishing face of Gaia*. Akadémiai Kiadó Zrt.
- 345 Lovelock, J. E., & Margulis, L. (1974). Atmospheric homeostasis by and for the  
346 biosphere: the gaia hypothesis. *Tellus A*, 26(1–2), 1–2.  
347 <https://doi.org/10.3402/tellusa.v26i1-2.9731>
- 348 Marais, A., Adams, B., Ringsmuth, A. K., Ferretti, M., Gruber, J. M., Hendrikx, R.,  
349 ... van Grondelle, R. (2018). The future of quantum biology. *Journal of the*  
350 *Royal Society Interface*, 15(148). <https://doi.org/10.1098/rsif.2018.0640>
- 351 MD. Nagy, K. (2008). Clinical and experimental tests carried out with medicinal  
352 water and medicinal caves containing radon.
- 353 Moya, D. S., K.S.G., & Veira, D. M. (2013). " Hyperlink "  
354 Retrieved from: <http://www.agr.gc.ca/eng/abstract/?id=30992000000542%22>  
355 Standardization of a non-invasive methodology to measure cortisol in hair  
356 of beef cattle.%22, *Livestock Science*, 158(1-3)
- 357 Nagy, A. D. (2010). A cirkadián óra génszintű vezérlése-vizsgálatok csirke  
358 tobozmirigy modellen. Pécsi Egyetem.
- 359 Nelson, P. J., & Rudnick, G. (1982). The role of chloride ion in platelet serotonin  
360 transport. *Journal of Biological Chemistry*, 257(11), 6151–6155.
- 361 Olson, B. E., & Wallander, R. T. (2001). Orientation of beef cattle grazing foothill  
362 winter range in Montana. *Journal of Animal Science*, 79(Supplement 2), 114–  
363 115.

- 364 Pavlik, I. (1967). The fate of light air ions in the respiratory pathways. *Int J*  
365 *Biometeorol* 11, 175–185. <https://doi.org/10.1007/BF01426844>
- 366 Pfeifer, Y., & Sulman, F. G. (1969). Effect of Negative Air Ion Treatment on Blood  
367 Serotonin in Weather Sensitive Patients, 3–6.
- 368 Phelps, J. M. D. (2005). From stress to genes, from mind to molecules-Chapter 9.  
369 Retrieved from: <http://www.psycheducation.org/mechanism/9TrophicFactors.htm%22>  
370 <http://www.psycheducation.org/mechanism/9TrophicFactors.htm>
- 371 Reed, D.D., Jones, E.A., Mroz, G.D. et al. (1993). Effects of 76 Hz electromagnetic  
372 fields on forest ecosystems in northern Michigan: Tree growth. *Int Journal of*  
373 *Biometeorology* 37, 229–234. <https://doi.org/10.1007/BF01387529>
- 374 Rikitake, T. (1994). Nature of Macro-Anomaly Precursory To an Earthquake. *Journal*  
375 *of Physics of the Earth*, 42(2), 149–163. <https://doi.org/10.4294/jpe1952.42.149>
- 376 Serrano, C., Reis, A. H., Rosa, R., & Lucio, P. S. (2006). Influences of cosmic  
377 radiation, artificial radioactivity and aerosol concentration upon the fair-weather  
378 atmospheric electric field in Lisbon (1955–1991). *Atmospheric Research*, 81,  
379 236-249.
- 380 Soyka, F. (1977). *The ion effect*. ISBN 0-553-14388-3.
- 381 Stubbs, T. J., Glenar, D. A., Farrell, W. M., Vondrak, R. R., Collier, M. R., Halekas,  
382 J. S., & Delory, G. T. (2011). On the role of dust in the lunar ionosphere.  
383 *Planetary and Space Science*, 59(13), 1659–1664.  
384 <https://doi.org/10.1016/j.pss.2011.05.011>
- 385 Tchijewski, A. L. (1960). *Air Ionization: Its Role in the National Economy*.

- 386 Thornhill, W. and Talbott, D. (2007). *The Electric Universe*. Milkamar Publishing
- 387 Völgyesi, L. (1982). *Geofizika*. (3rd 2002). Műegyetemi Kiadó.
- 388 Völgyesi, L. (2010). A gravimetria mai jelentősége és helyzete Magyarországon.  
389 *Magyar Tudomány*, 2012(6), 706-723.
- 390 Wahlin, L. (1989). *Atmospheric electrostatics*. ISBN 0 471 91202 6.
- 391 Ward, P. D., & Brownlee, D. (2000). *Rare Earth*. Copernicus books.
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