Hyperbolic Circadian Rhythms in Plants

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ABSTRACT

The response of the plant to light and darkness presupposes a perception and measurement of time to adjust its internal metabolic and physiological rhythms. This explains why plants obtain advantages from circadian control. Helix-shaped structures and hyperbolic patterns are very common in nature. There are several hyperbolic curves in plant physiology, which have to do with the rate of transpiration, nutrient absorption, photosynthesis, and metabolic regulations of plants. The aim of this work is to study circadian rhythms in plants, in relation to the hyperbolic curves that occur in nature. Geomagnetic rhythms can act as a time clock to organize physiological rhythms. This means that the biorhythms of plants and animals follow hyperbolic curves, synchronized with the hyperbolic lines of the Earth's magnetic field. The movement of light to the observer's eye is through hyperbolic curves of space-time, similar to the hyperbolic curves of the lines of force of a magnet, the Earth's magnetic field, and an electromagnetic field. When a moving plant organ moves away from or approaches a nearby observer, it does so following hyperbolic lines of force. There is a close relationship between many hyperbolic curves that occur in plant physiology and the hyperbolic curves of space-time that occur in nature. Plant circadian rhythms are related to the hyperbolic nature of light.

Keywords: plants; circadian; rhythms; medicine; hyperbolic; light; space; time; genetic; evolution.

INTRODUCTION

First, we must consider three concepts:

a) "Hyperbolic curve": it is an open geometric figure with two branches, which is obtained by cutting a straight cone by a plane oblique to the axis of symmetry. The plane does not have to be parallel to the axis of the cone, and the hyperbola will be symmetrical in any case [1].

b) "Hyperbolic Medicine": it refers to the study of hyperbolic curves that occur in the physiology of a living being, especially in humans, in relation to other hyperbolic curves that may be found in nature, such as circadian rhythms, electromagnetic fields, expansion-contraction systems in motion, and space-time relativity [2-12]. This concept can be applied to any living being, animal or plant.

c) "Circadian rhythms": they are biological cycles that last approximately 24 hours and that regulate various physiological processes in plants and animals. It has been thought that time and the rhythms of the biological clock are in the genetic code. These are regulated by environmental signals (light, temperature, humidity, rest, sound) and are synchronized to approach the frequency of the stimulus [13,14]. In humans, it has been described that these circadian rhythms can follow hyperbolic curves [15,16].

In the case of plants, these rhythms allow them to adapt to changes in their environment, especially light and dark cycles. Daily biological rhythms were first described in 1729 by the French scientist Jean-Jacques de Mairan, who observed that mimosa plants (Mimosa pudica L.) had grown in natural light-dark cycles and, when transferred to permanent darkness, continued to open and close their leaves with a rhythmicity close to 24 hours. Years later, Linnaeus proposed that the opening and closing of the petals of various plants was controlled by daily light-dark rhythms [17]. Different species, and different individuals of the same species, often have slightly different but constant rhythms [18]. The circadian clock is an evolutionary advantage for organisms that possess it, as it allows them to anticipate changing external conditions [17]. Circadian rhythms are an evolutionary adaptation to life on a rotating planet, where light and temperature levels fluctuate over 24-hour periods, and this affects our physiology [13,19]. The response of the plant to light and darkness presupposes a perception and measurement of time, to adjust its internal metabolic and physiological rhythms [20]. When the clock period of plants coincides with the clock of the environment, they contain more chlorophyll, fix more carbon, grow faster, and survive better than plants with circadian periods different from their environment.

This explains why plants obtain advantages from circadian control [21]. Table 1 lists its main aspects [19,22-25].

From a biochemical point of view, the main relationships between circadian rhythms and plant physiology are:

A) Regulation of photosynthesis: Chlorophyll is synthesized rhythmically in response to the circadian clock. The activation of photosynthetic enzymes such as ribulose-1,5-bisphosphate carboxylase/oxygenase (Rubisco) is regulated by the circadian clock.

B) Regulation of sugar metabolism: During the day, plants accumulate starch as an energy reserve and at night, starch is broken down into sugars to maintain nocturnal metabolism. Gluconeogenesis and glycolysis are also subject to circadian regulation, so that plants can adjust energy production according to daily needs.

C) Production of hormones (abscisic acid, ethylene) and secondary metabolites (alkaloids, flavonoids and terpenoids) are regulated by the circadian clock.

D) Nitrogen cycle: The absorption and assimilation of nitrogen by plants is used for the synthesis of amino acids and proteins, and is regulated by the circadian clock. The enzyme nitrate reductase shows a circadian activity, which optimizes the conversion of nitrates into forms usable by the plant at the most appropriate times of the day.

E) Oscillation of calcium levels: The calcium ion (Ca^{2+}) acts as a second messenger in many cellular pathways and its intracellular levels oscillate in a circadian manner. These calcium oscillations are linked to the regulation of processes such as the opening and closing of stomata, gene expression and the response to environmental stimuli.

F) Control of gene expression: Some photosynthesis genes are controlled by circadian rhythms, controlled by the photoperiod and by the endogenous clock [17]. The first two proteins pointed out as possible components of the circadian clock in plants were CCA-1 and LHY. Null mutants of the CCA-1 and LHY genes have been identified, which exhibit shorter periods in rhythmicity, indicating that both are components of the central oscillator [17]. In Arabidopsis the circadian clock participates in the control of flowering by regulating the expression level of the CONSTANS and FT genes [17]. The clock consists of several genes that control each other through feedback loops [19].

G) Interaction with light and photoreceptors: Plants possess photoreceptors such as cryptochromes and phytochromes, which not only detect light, but are also involved in the synchronization of the circadian clock. These photoreceptors influence the expression of circadian genes, modulating the plant's response to light and ensuring that biochemical processes are aligned with the day-night cycle.

H) Free radical homeostasis: The production of reactive oxygen products is a byproduct of photosynthesis and cellular respiration. Circadian rhythms regulate the expression of antioxidant enzymes such as superoxide dismutase and catalase, which protect the plant from oxidative damage (detoxification).

Most methods for studying circadian rhythms are based on the use of genetic modification. However, a reliable method for measuring the "clock" of some plants is to use "delayed fluorescence" (light emitted by plants after they are illuminated, and which persists for a long time when they are placed in the dark). The technique works by measuring the delayed fluorescence of photosystem II [24].

Helix-shaped structures and hyperbolic patterns are very common in nature. Many processes that occur in human physiology, related to circadian rhythms, are hyperbolic curves [2,12,13,15,16,26-47]. There are several hyperbolic curves in plant physiology, that are related to the rate of transpiration, nutrient absorption, photosynthesis, and metabolic regulations of plants [22,23]. The aim of this work is to study circadian rhythms in plants, in relation to the hyperbolic curves that occur in nature.

MATERIAL AND METHODS
A bibliographic review of scientific works related to circadian rhythms in plants and humans was carried out using Internet search engines and various databases to locate similarities and differences between them. We then studied, within the concept of hyperbolic medicine, the relationship of these circadian rhythms with the hyperbolic curves found in nature and their synchronization with them.

TABLE 1: Characteristics of circadian rhythms in plants.

A)	They use circadian rhythms to measure the length of day and night. Some plants have flowers according to the photoperiod.
B)	They regulate the opening and closing of stomata to allow gas exchange and optimize photosynthesis.
C)	They influence plant growth, regulating stem elongation and cell division, to coincide with the best environmental light conditions.
D)	They regulate the activity of certain enzymes and metabolic pathways in the synthesis of sugars and cellular respiration, synchronizing with the day and night cycles.
E)	They intervene in stress situations, such as drought, responses to biotic and abiotic stress, flowering time, mineral uptake, photosynthesis, defense against pests, water regulation, nitrogen fixation, or to convert carbon into useful products.
F)	It is controlled by genes and proteins (TOC1, CCA1, LHY) that interact with each other through feedback.

RESULTS

Table 2 shows the similarities and differences between the circadian rhythms of plants and animals [22,48]. The unique characteristics of circadian rhythms in plants are found in Table 3 [17-20,22,25]. According to the bibliographic review carried out, we know that conic images in nature represent the movement of light through hyperbolic curves of space-time [26], and exist independently of the longitude and latitude of the Earth where they are observed [27]. The lines of force of a magnet, of the Earth's magnetic field, and an electromagnetic field are hyperbolic curves of space-time [2-12,15,16,26-32,49-60]. Hyperbolic curves exist in plants, as shown in Table 4 [22,23]. Many curves occurring in human physiology are hyperbolas and are related to hyperbolic curves of space-time occurring in nature [2,11,12,15,16,26-47].

TABLE 2: Circadian rhythms in plants and animals.

A) Similarities
They follow a synchronized 24-hour daily light-dark cycle. In both cases, they are controlled by genes and proteins through positive and negative feedback.

B) Differences
a) The circadian clock in plants is distributed in the cells of the entire organism, without a centralized structure. In animals, especially in vertebrates, the circadian clock is centralized in the suprachiasmatic nucleus (SCN) in the hypothalamus.
b) In plants, these processes are linked to the physical environment, such as light and temperature. In animals, the circadian clock regulates physiological functions (body temperature, hormone secretion) and complex behaviors (sleep-wake cycle, feeding, and locomotor activity).
c) Plants use photoreceptors such as phytochromes and cryptochromes to detect light. In animals, light is detected by photosensitive cells in the eyes or other parts of the body, which send signals to the SCN.
d) Plants are more flexible and can adjust to different environmental conditions. Animals are more rigid, which can lead to imbalances such as jet lag when light-dark cycles suddenly change.
e) Regarding evolution, in plants, the circadian clock acts to improve photosynthesis and regulate flowering at the right time of year. In animals, this clock is more oriented to regulating internal physiological processes.

TABLE 3: Unique circadian rhythms in plants.

A)	Decentralized distribution of the circadian clock: in all cells of the organism.
B)	Regulation of photosynthesis: through the opening and closing of stomata and the activity of photosynthetic enzymes, optimizing light capture and the use of CO_2 at the most appropriate times of the day.
C)	Plants use circadian rhythms to measure the length of day and night, controlling flowering (photoperiod). The photoperiod regulates flowering, tuber formation, onset of dormancy, cambium activity, senescence, leaf abscission, type of branching, plant succulence, anthocyanin biosynthesis, essences, cold resistance. The photoperiod allows the plant's development cycle to be adjusted to the most advantageous climate.
D)	Responses to specific light stimuli: plants have specific photoreceptors, such as phytochromes and cryptochromes, which detect different wavelengths of light (red, far red, and blue).
E)	Adjustment to changes in day length: circadian rhythms in plants are flexible and can adjust to variations in day and night, to synchronize external rhythms of the environment with their own internal rhythms.
F)	Regulation of daily growth and development of stems and roots, as well as the direction of growth (tropisms).
G)	Production and release of volatile products for defense against herbivores or attracting pollinators.
H)	Regulation of resistance to stress (drought, salinity, extreme temperatures). Low temperatures can regulate dormancy and germination.
I)	Coupling between metabolism and circadian cycles to regulate the synthesis of sugars, amino acids, and other secondary metabolites.
J)	Dependence on the environment, as plants can adjust to light, temperature, and other environmental factors.

**TABLE 4:** Hyperbolic curves in plants.

• Transpiration rate as a function of stomatal aperture
• Transpiration as a function of soil water potential
• Uptake of an element as a function of time
• Uptake rate as a function of nutrient concentration
• Plant growth as a function of nutrient medium concentration
• Total biomass produced as a function of resource level
• Development rate as a function of temperature
• Growth rates as a function of total plant leaf area
• Relationship between photosynthesis and light intensity
• Relationship between photosynthesis and leaf area index
• Photoperiodic responses to light
• Light attenuation as a function of penetrated leaf area
• Effect of Nicotinamide adenine dinucleotide phosphate (NADPH) on ferredoxin-catalyzed cyclic photophosphorylation

- Atmospheric CO_2 concentration on photosynthesis rate
- Evolution of Desoxyribonucleic acid (DNA) in leaves with age

DISCUSSION

Before discussing hyperbolic aspects of plants, we must explain hyperbolic characteristics of the space-time in which we live. That is, the hyperbolic geometry of the Earth and how it affects the plants that live on it.

The eye estimates distance based on the decrease in size of objects and the angle of convergence of lines [61]. Objects are smaller as their distance from the observer increases. What we see forms a conical beam, with its vertex at the point of view. Conical perspective is the one that most closely approximates the reality we see [62]. Photographs produce this type of perspective by collecting the projected image [62-67]. Current work indicates that a conical perspective represents images that travel at the speed of light to the observer's eye, following hyperbolic curves of space-time, which are similar to the hyperbolic lines of force of a magnet [26] (Figure 1). A conical perspective image is a static image. It is an instantaneous image. When we see this moving image, the lines become curves, and we observe a hyperbola (Figure 1, A and B). Conic perspectives are hyperbolic curves of space-time [26]. In nature, the usual form is the curve. The straight line is only a part of this curve. If we observe the lines of force of a magnet and the magnetic field of the Earth, we perceive that they are hyperbolic images [2-10,16,26-32,49-53,68] (Figure 1C). If a leaf of a moving plant approaches an observer, he perceives its dimensions perpendicular to the movement (height Y, width Z) as larger the closer it is to him (Figure 1B). On the contrary, if it moves away from the observer, he perceives those dimensions perpendicular to the movement as smaller (Figure 1A). In both cases, the observer perceives hyperbolic images when the leaf of the plant approaches or moves away. Human vision is hyperbolic because the space in which we live is distorted by "general hyperbolic curves" that exist at any longitude and latitude of the Earth's geography [27]. Previous studies indicate that animals with binocular vision have their perception in the farthest part of a hyperbolic image, while animals with lateral vision have it in the closest part of that hyperbolic image [49].
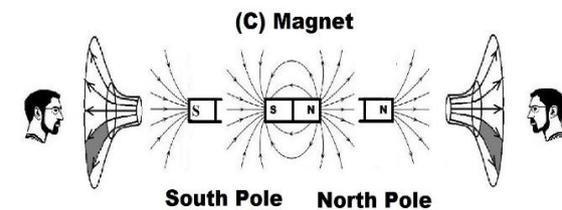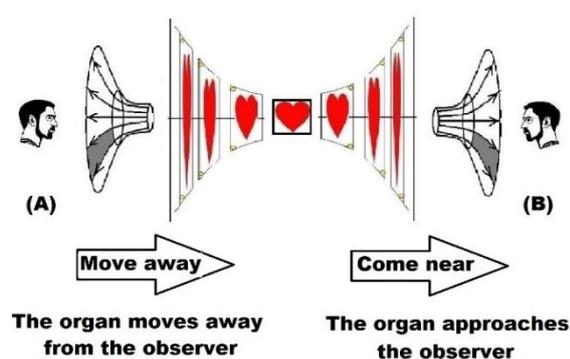

FIGURE 1: Hyperbolic image of a heart-shaped leaf of Epipremnum aureum, when it moves away (A) or towards (B) an observer. This image is similar to the hyperbolic lines of force of a magnet (C).

In a simple magnet and the Earth's magnetic field, there are lines of force that have a hyperbolic shape [2-12,15,16,26-32,49-55]. Also, the lines of force of electromagnetic fields are hyperbolic curves [2-12,27,28,31,32,49,53,56-60]. It has been indicated that electromagnetic fields have effects on human physiology, through hyperbolic curves [2-12,15,16,26-32,49-55]. We can deduce that they would also have effects on other living beings, such as plants, through these hyperbolic curves. Images of nature are hyperbolas, because the deformed space in which we live is hyperbolic (Figure 2).

This hyperbolic space conditions the physiology of any living being. Therefore, plants must adapt their physiology to the hyperbolic nature in which they live. Geomagnetic rhythms can act as a time clock to organize physiological rhythms. This means that the biorhythms of plants and animals follow hyperbolic curves, synchronized with the hyperbolic lines of the Earth's magnetic field. If external stimuli are applied that modify the hyperbolic physiological curves, they have a tendency to synchronize again to become hyperbolas. Cellular physiological processes are subject to permanent synchronization. Plant and animal cells synchronize their physiological processes to create hyperbolic curves similar to those that exist in nature [2-12,16,28-30,68].

In the plant, there is a longitudinal axis, with one end in the stem and another in the root (axial polarity). In the brown alga Fucus, this polarization is initiated by light (the less illuminated part will be the rhizoid end). Each individual cell has polarized molecules that form a cytoskeleton of longitudinally oriented fibrous proteins. Polarity is due to the uneven distribution of cytoplasmic calcium between the two poles, which can be induced by light gradients [20]. That is, by electromagnetic waves that act through hyperbolic space-time curves. The measurement of time involves rhythmic changes in the cell membrane, either in the protein components, in the phospholipids, or in both [18]. From the above, we can think of a synchronization of these circadian rhythms with the hyperbolic nature of light, and these conditions govern all the physiological processes of plants and animals.
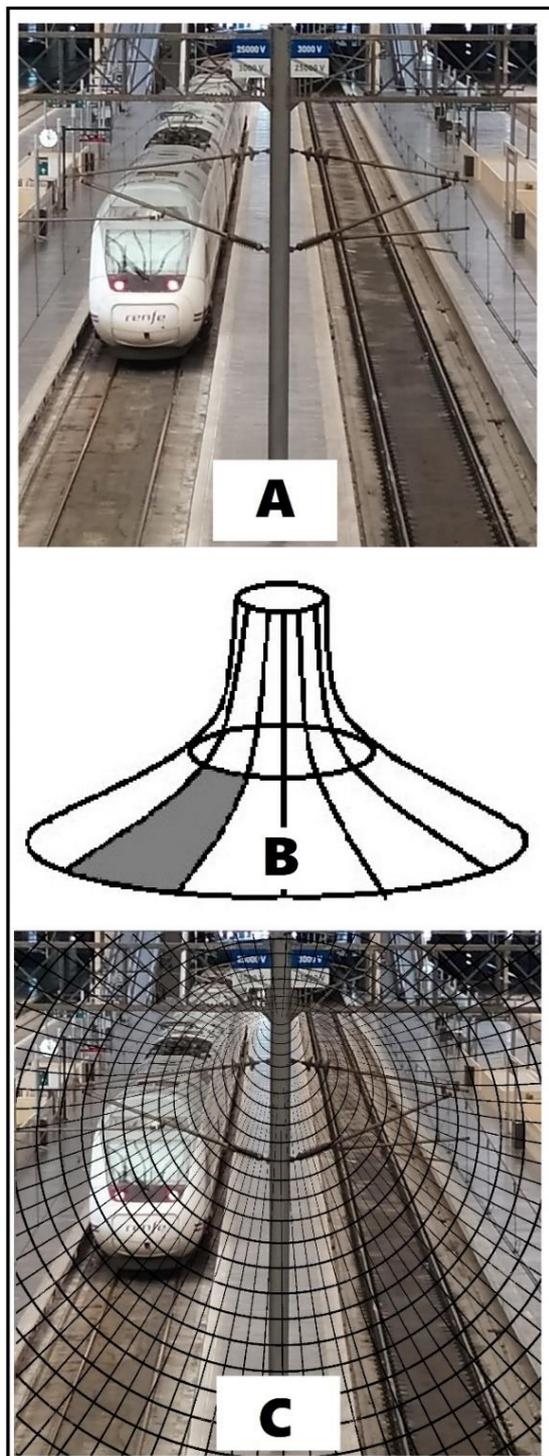
FIGURE 2: Image taken at Zaragoza train station (A). Scheme of a hyperbola (B). In C is image A is observed as the hyperbola B.

CONCLUSIONS

1. The movement of light to the observer's eye is through hyperbolic curves of space-time, similar to the hyperbolic curves of the lines of force of a magnet, the Earth's magnetic field, and an electromagnetic field.
2. When a moving plant organ moves away from or approaches a nearby observer, it does so following hyperbolic lines of force.
3. There is a close relationship between many hyperbolic curves that occur in plant physiology and the hyperbolic curves of space-time that occur in nature.
4. Plant circadian rhythms are related to the hyperbolic nature of light. Plant physiology is adapted to this hyperbolic nature in which we live.

REFERENCES

[1] Chambadal, L. (1984). Diccionario de matemáticas. Pp. 139-141. Barcelona, Spain: Ediciones Grijalbo, S.A.

[2] González-González, J.M. (2022). Hyperbolic Medicine. International Journal of Science and Research (IJSR), 11(2), 329-334. Doi: 10.21275/SR22205174553

[3] González-González, J.M. (2022). Medicina hiperbólica. Efectos del tiempo y el espacio en la fisiología humana. Berlin: Editorial Académica Española. ISBN-13: 978-3-659-65432-9

[4] González-González, J.M. (2022). Hyperbolic medicine. Effects of time and space on human physiology. Berlin: Lap Lambert Academic Publishing. ISBN-13: 978-620-4-98451-3

[5] González-González, J.M. (2022). Hyperbolic medicine. Effects of time and space on human physiology. Berlin: Our Knowledge Publishing. ISBN-13: 978-620-5-04565-7

[6] González-González, J.M. (2022). Medecine hyperbolique. Effets du temps et de l'espace sur la physiologie humaine. Berlin: Editions Notre Savoir. ISBN-13: 978-620-5-04566-4

[7] González-González, J.M. (2022). Hyperbolische medizin. Auswirkungen von Zeit und Raum auf die menschliche Physiologie. Berlin: Verlag Unser Wissen. ISBN-13: 978-620-5-04550-3

[8] González-González, J.M. (2022). Medicina iperbolica. Effetti del tempo e dello spazio sulla fisiologia umana. Berlin: Edizioni Sapienza. ISBN-13: 978-620-5-04567-1

[9] González-González, J.M. (2022). Medicina Hiperbólica. Efeitos do tempo e do espaço na fisiologia humana. Berlin: Edições Nosso Conhecimento. ISBN-13: 978-620-5-04568-8

[10] González-González, J.M. (2022). Гиперболическая медицина. Влияние времени и пространства на физиологию человека. Berlin: Sciencia Scripts. ISBN-13: 978-620-5-04570-1

[11] González-González, JM. (2024). Compendio de medicina hiperbólica. Efectos del tiempo y el espacio en la fisiología humana. Berlín: Editorial Publicia, OmniScriptum GmbH & Co.KG. ISBN: 978-3-639-55086-3.

[12] González-González, JM. (2024). Compendium of hyperbolic medicine. Effects of time and space on human physiology. Berlin: Lambert Academic Publishing. ISBN: 978-620-8-17147-6

[13] Barcia Salorio, D. (2007). Ritmos biológicos y periodicidad en psiquiatría. Murcia: Cuaderna editorial.

[14] Rojo Sierra, M. (1984). La asimetría cerebral y la experiencia psicológica y patológica del tiempo. Valencia: Sancho Artes Gráficas.

[15] González-González, J.M. (2018). Circadian rhythms and dental caries. International Journal of Current Research, 10(7), 71616-71618.

[16] González-González, J.M. (2020). Psychological and physiological time, in childhood and old age. Synchronization with the Earth´s hyperbolic magnetic field. EAS J Med Surg, 2(6), 140-145.

[17] Capel, J., Lozano, R., Martínez-Zapater, J., & Jarrillo, J. (2003). Ritmos y relojes circadianos de las plantas. Ecosistemas, 12(1). [Online]. Available:https://www.revistaecosistemas.net/index.php/ecosistemas/article/view/249 [Accessed: August 24, 2024].

[18] Anonymous. (2021). Ritmos circadianos: el reloj biológico. Blog del COBCM. Blog Oficial del Colegio Oficial de Biólogos de la Comunidad de Madrid. [Online]. Available: https://cobcm.net/blogcobcm/2021/11/22/ritmos-circadianos-reloj-biologico/ [Accessed: August 24, 2024].

[19] Hubbard, K. (2020) ¿Cómo luchan las plantas contra el jet-lag? Understand article. Science in school, 48. [Online]. Available: https://www.scienceinschool.org/es/article/2020/how-plants-beat-jet-lag-es/ [Accessed: August 24, 2024].

[20] Barceló Coll, J., Nicolás Rodrigo, G., Sabater García, B., Sánchez Tamés, R. (2023). Fisiología vegetal. Madrid: Ediciones Pirámide.

[21] Dodd AN et al. (2005). Plant circadian clocks increase photosynthesis, growth, survival, and competitive advantage. Science, 309: 630–633. doi: 10.1126/science.1115581

[22] Barceló Coll, J., Nicolás Rodrigo, G., Sabater García, B., Sánchez Tamés, R. (2009). Fisiología vegetal. Madrid: Ediciones Pirámide.

[23] Loomis, R.S. & Connor, D.J. (2002). Ecología de cultivos. Productividad y manejo de sistemas agrarios. Madrid: Ediciones Mundi-Prensa.

[24] Álvarez, J.E. (2019). Iluminación Hortícola. [Online]. Available: https://smart-lighting.es/hablemos-del-ritmo-circadiano-las-plantas-utilizacion-mejorar-cultivos/ [Accessed: August 24, 2024].

[25] McClung, CR. (2019.) The plant circadian oscillator. Biology. 8: 14. doi: 10.3390/biology8010014

[26] González-González, J.M. (2021). Relationship between conical perspective, hyperbolic curves, and hyperbolic medicine. International Journal of Scientific Advances (IJSCIA), 2(5), 704-707. Doi: 10.51542/ijscia.v2i5.5

[27] González-González, J.M. (2021). Hyperbolic Medicine: General and Local Hyperbolic Curves on Earth, Influencing Human Physiology. International Journal of Scientific Advances (IJSCIA), 2(4), 630-635. Doi: 10.51542/ijscia.v2i4.29

[28] González-González, J.M. (2020). Hyperbolic curves in Medicine and the Earth´s magnetic field. International Journal of Science and Research (IJSR), 9(3), 1620-1624.

[29] González-González, J.M. (2020). Hyperbolic Medicine. A Space-Time Synchronization External to the Human. International Journal of Science and Research (IJSR), 9(11), 234-239.

[30] González-González, JM. (2020). Space-time synchronization in hyperbolic medicine. International Journal of Innovative Studies in Medical Sciences (IJISMS), 4(5), 17-20.

[31] González-González, J.M. (2022). Helical hiperbolic magnetic field in nerves, when act as current conductors. Glob Acad J Med Sci, 4(6), 286-292.

[32] González-González, J.M. (2023). Helical hyperbolic structure of the genetic code. Genetic hyperbolic medicine. Sci Res Jr Med Sci, 3(3), 35-41.

[33] Akitoshi, Seiyama. (2006). Virtual cooperativity in myoglobin oxygen saturation curve in skeletal muscle in vivo. Dynamic Medicine, 5, 3.

[34] Melvin Khee-Shing Leow. (2007). Configuration of the hemoglobin oxygen dissociation curve demystified: a basic mathematical proof for medical and biological sciences undergraduates. Adv Physiol Educ, 31, 198-201.

[35] Werner, Müller-Esterl. (2008). Bioquímica. Fundamentos para Medicina y Ciencias de la Vida. Barcelona: Editorial Reverte.

[36] Atassi, M.Z., Childress, C. (2005). Oxygen-binding heme complexes of peptides designed to mimic the heme environment of myoglobin and hemoglobin. Protein J, 24(1), 37-49.

[37] Tallarida, R.J. (2016). Drug Combinations: Tests and Analysis with Isoboles. Curr Protoc Pharmacol, 72, 1-19.

[38] Doelle, H.W. (1982). Kinetic characteristics and regulatory mechanisms of glucokinase and fructokinase from Zymomonas mobilis. European J Appl Microbiol Biotechnol, 14, 241-246.

[39] Vickrey, J.F., Herve, G. & Evans, D.R. (2002). Pseudomonas aeruginosa Aspartate Transcarbamoylase. Characterization of its catalytic and regulatory properties. The journal of biological chemistry, 277(27): 24490-24498.

[40] Utzschneider, K.M., Prigeon, R.L., Carr, D.B., et al. (2006). Impact of Differences in Fasting Glucose and Glucose Tolerance on the Hyperbolic Relationship Between Insulin Sensitivity and Insulin Responses. Diabetes Car, 29, 356-362.

[41] Retnakaran, R., Shen, S., Hanley, A.J., Vuksan, V., Hamilton, J.K. & Zinman, B. (2008). Hyperbolic Relationship Between Insulin Secretion and Sensitivity on Oral Glucose Tolerance Test. Obesity, 16, 1901-1907.

[42] Mizuo, J., Nakatsu, T., Murakami, T., et al. (2000). Exponential hyperbolic sine function fitting of heart rate response to constant load exercise. Jpn J Physiol, 50(4), 405-12.

[43] Seiryo Sugiura, Hiroshi Yamashita, Masataka Sata, et al. (1995). Force-velocity relations of rat cardiac myosin isozymes sliding on algal cell actin cables in vitro. Biochimica et Biophysics Acta, 1231, 69-75.

[44] Iwamoto, H., Sugaya, R. & Sugi, H. (1990). Force-velocity relation of frog skeletal muscle fibres shortening under continuously changing load. Journal of Physiology, 422, 185-202.

[45] Whinnery, T., Forster, E.M. & Rogers, P.B. (2014). The +Gz recovery of consciousness curve. Extreme Physiology & Medicine, 3, 9.

[46] Zhou, Y., Smith, B.H. & Sharpee, T.O. (2018). Hyperbolic geometry of the olfactory space. Sci. Adv, 4(8), eaaq1458.

[47] Gómez Argellés, J. (2016). Cuando las rectas se vuelven curvas. Las geometrías no euclídeas. Barcelona: Ed. RBA Coleccionables.

[48] Mas, P. (2011). El reloj circadiano: las plantas siguen el ritmo [Online]. Available: https://mujeresconciencia.com/2015/05/10/el-reloj-circadiano-las-plantas-siguen-el-ritmo/[Accessed: August 24, 2024].

[49] González-González, J.M. (2021). The hyperbolic vision in humans and other animals. International Journal of Science and Research (IJSR), 10(10), 1241-1246.

[50] González-González, J.M. (2017). Teleportation of humans and their organs in the treatment of cancer. International Journal of Current Research, 9(6), 52659-52663.

[51] González-González, J.M. (2017). Teleportation of human organs in the treatment of diseases, hyperbolic spaces, and unified fields. International Journal of Current Research, 9(9), 57340-57342.

[52] González-González, J.M. (2019). Physical Theory of Premonition in Medicine. International Journal of Science and Research (IJSR), 8(5), 1340-1344.

[53] González-González, J.M. (2022). Magnetic Monopoles and Lenz's Law in Hyperbolic Medicine. International Journal of Scientific Advances (IJSCIA), 3(5), 789-795. Doi: 10.51542/ijscia.v3i5.20

[54] Garcia Santemases, J. (1978). Física general. Octava edición. Madrid: Ed. Paraninfo.

[55] Halliday, D. & Resnick, R. (1990). Física. Parte 2. Mexico: Compañía Editorial Continental, S.A.

[56] Valentinuzzi, M.E. (2004). Magnetobiology: a historical view. IEEE Eng Med Biol Mag, 23(3), 85-94.

[57] Sachiko Yamaguchi-Sekino, Masaki Sekino, Shoogo Ueno. (2011). Biological effects of electromagnetic fields and recently updated safety guidelines for strong static magnetic fields. Magn Reson Med Sci, 10(1), 1-10.

[58] Richard H W Funk, Thomas Monsees & Nurdan Ozkucur. (2009). Electromagnetic effects - From cell biology to medicine. Prog Histochem Cytochem, 43(4), 177-264.

[59] Zannella, S. (?). Biological effects of magnetic fields. [Online]. Available: https://cds.cern.ch/record/1246526/files/p375.pdf?version=1 [Accessed: October 18, 2023].

[60] Ruz Ruiz, M. et al. (2010). Grupo de investigación PRINIA de la Universidad de Córdoba. Efectos sobre la salud humana de los campos magnéticos y eléctricos de muy baja frecuencia (elf). Sevilla: Junta de Andalucía. Consejería de Empleo.

[61] López Vílchez, I., García López, R.M., Posse, P. (1992). Perspectiva: Ciencia y Magia de la representación. Junta Andalucía. Granada: Consejería de Innovación, Ciencia y Empresa.

[62] Bartolomé Ramírez, R. (2011). Perspectiva: fundamentos y aplicaciones. Axonométrico, caballera, cónica. Material didáctico ingenierías, nº 17. La Rioja: Servicio de publicaciones. Universidad de la Rioja.

[63] Hernando Pérez, J. (?). La Perspectiva Cónica en la Colección de la Escuela Barroca Española del Museo del Prado. [Online]. Available: https://content.cdnprado.net/doclinks/pdf/aprende/educacion/fp/i-encuentro/jesus-hernado-perez.pdf [Accessed: September 13, 2020]

[64] Anonymous. (?). Perspectiva. [Online]. Available:https://es.wikipedia.org/wiki/Perspectiva [Accessed September 13, 2020]

[65] Beltrán Polaina, J.M. (2006). Estudio de la perspectiva cónica mediante la conjunción del espacio real y el proyectado utilizando la imagen digital. Tesis doctoral. Universidad de Bellas Artes. Granada: Editorial de la Universidad de Granada.

[66] Salvador Giménez, M.A. (2015). Introducción a los sistemas de representación lineal: perspectiva cónica. Master en profesorado de educación secundaria obligatoria y bachillerato, formación profesional y enseñanza de idiomas. Trabajo fin de Master. Almería: Universidad de Almería.

[67] Anonymous. (?). Perspectiva cónica. [Online]. Available:https://es.wikipedia.org/wiki/Perspectiva_c%C3%B3nica [Accessed: September 13, 2020]

[68] González-González, J.M. (2023). Hyperbolic genetic mechanism of human evolution. International Journal of Scientific Advances (IJSCIA), 4(5), 773-779.
Doi: 10.51542/ijscia.v4i5.18