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Forest – the photosphere of life in the Earth's atmosphere

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Abstract. The evolution of the vertical, long distance water transport, overcoming gravitation, by trees during the Devonian, initiated the emerging of forest ecosystems extending the photosphere of life further into the Earth's atmosphere. The origin of woody tissues is likely associated with genome mutations in primitive green plants, which inhabited the land about 350 million years ago. Most probably, only two mutations were required – one allowing the synthesis of lignin and the second, enabling the autolysis of protoplast in the maturing cellular woody elements. Developing forest ecosystems formed the most productive environments, in which sunlight-dependent metabolic processes of life reached further into the atmosphere while at the same time allowing more water to be stored on the land surface, which in turn allowed for the evolution of numerous heterotrophic organisms. This property of the forest could therefore be considered an important factor in the evolution of hominids, which eventually contributed to the development of the Homo sapiens culture.

Keywords: Forest, emergent property, life property, evolution

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1. Introduction

"Property" is a concept from traditional logic that denotes the characteristics of a given thing – understood as a physical system. Usually, it is a measurable feature and its choice and characteristics depend on the interests of the observer.

The determination of forest properties most often refers to the objectives of its protection and use. Knowledge about forest properties, in this sense, is the main subject of education in the forestry profession, that is, the content of study programs at forest faculties. It is also usually the main subject characterising research programs and monographic studies as the basis for categorising forms or improving management methods in forestry (Rykowski 2006; Podgórska, Sierota 2010). This is the source of complexity of the foresters' specialization in the education process, which is a presentation of the interdependence of various aspects of knowledge in the field of applied breeding methods, utilization, protection, engineering, economics and performance of selected recreational functions of the forest. In practice, such concepts of properties or characteristics of forest ecosystems are the final aim of forest management. However, the development of forestry in the future requires the progress of knowledge and improvement of forest management methods, which is not possible without detailed research on the functions of forest ecosystems as the environment of life on Earth.

Initial considerations on this subject were presented by Zięba (2015):"...when a system comprised of components reaches a certain level of complex organization, it begins to reveal new emergent properties, which are not predictable on the basis of the properties and the structural relations characteristic for the constitutive parts of the system" and further: "Forest systems are characterised by their entirety, specific features that cannot be derived from the parts examined separately. It is a singular organization characterised by the properties and the functioning of the whole".

Determining these forest properties is still not obvious and is connected with the necessity to characterize the basis of the evolution of life on Earth. There is a need to indicate those properties of the biocenotic structure, which enabled

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the evolution of life in the Earth's terrestrial environment. These include elements of paleobiology, genetics and the physiology of the development of woody plants.

2. Evolution and the environment of life on Earth

Life is a property of the structure of material systems that has enabled the acceleration of abiotic energy conversion processes (Lane 2016; Damasio 2018; Łagosz 2019). It has become a way of improving the processes of reducing the asymmetry of the structure of elementary particles, that is, the evolution of complex structural forms of the metabolism of matter and energy. This is also how the conditions of differentiating the properties and reproduction of organic compounds were created. The association of simple compounds of carbon, hydrogen, oxygen and nitrogen into organic compounds and their cyclic forms as amino acids was possible on Earth (most probably) only in an aqueous solution, because it is conditioned by the binding of the energy released in the process of the fission of H_2O particles in aliquid state, that is, at a temperature between the phases water solidification and evaporation. This concerns the utilization of the structure-forming potential of OH^- ions and the production of oxygen in molecular form, whose accumulation, especially in the Earth's atmosphere, provided the opportunity for the development of many life forms.

The beginning of the formation of amino acids, combining them into proteins with enzymatic properties and the synthesis of nucleotides and their polymers (RNA and DNA) is estimated at approximately 0.8 billion years after the creation of planet Earth. For millions of years, this was a period of the evolution of biogenetic processes in protein complexes and the development of molecular memory in the form of nucleotide sequences encoding the structure of enzymatic proteins. This, in turn, enabled the replication and mutagenesis of genetic information, and thus, the generational evolution of structural properties and the development of new life forms. At that time, the synthesis of phospholipids (hydrophobic substances with a bipolar structure) enabled primary cellular life forms to be released into the aquatic environment. It also made it possible to establish the location of many enzymatic proteins in the structure of membranes and to control the transport of ions or chemical compounds between the aquatic environment and the hydrated protoplast of primary cells.

Thanks to the previously created molecular memory of protein biogenesis and the specialization of the cytomembranes of primary cytoplasm, conditions for growth and reproduction were created through the division of simple forms of the cellular organism. The initiation of these new properties of the biological system, that is, about 2 billion years ago, has been accepted as the date of the initiation of life on Earth. However, these were still prokaryotic organisms (without a separate area for the cellular nucleus), which have survived until today in various forms of microorganisms. But already about 200 million years later, primordial eukaryotic (nuclear) organisms with a developed system of intracellular membranes appeared. Endomembranes, differentiated by the properties of enzymatic proteins (components of their structure), enabled the localization of various cellular metabolic processes, including the properties of using different energy sources formed earlier during the period of extracellular biosynthesis in the oceans.

These were both benthic organisms dependent on geothermal energy sources or on the release of the molecular bonds of minerals (e.g., archaea oxidising pyrite FeS_2, such as *Metallosphaera sedula* Huber et al. also found today in an Italian volcano) and other organisms developing in the near-surface area penetrated by sunlight (it is already dark at a depth below 150 m from the ocean's surface). Both life forms were still autotrophic, but they were characterised by a huge difference in the energy efficiency of their metabolism in favour of the biogenetic potential of photosynthesis. This difference in the manner of obtaining energy also stimulated the differentiation of the processes of synthesising structural substances, for example, the synthesis of fibrous cellulose molecules used in forming the cell wall surrounding the phospholipid membrane of cells. Thus, this was also the beginning of the evolution of two forms of biogenesis present to this day – autotrophs and heterotrophs, while heterotrophism (i.e., obtaining energy through the digestion of bodies of other organisms) enabled a further stage in the evolution of the potential to metabolize solar energy. Moreover, the process of photosynthesis also became a source of oxygen and the formation of high-energy adenosine triphosphate (ATP)bonds, thus, the most important energy transfer factor in the metabolism of organic compounds. In order to raise awareness about the scale of progress in the efficiency of energy transformation processes in biogenesis involving ATP, it is worth using Lane's information (2016) that, for example, a single human cell consumes about 10 million ATP molecules per second, which means that the total daily turnover of ATP in the human body consisting of about 40 trillion cells equals about 60–100 kg. These data are presented to show the scale of the properties of the metabolism of energy and matter in the cells of living organisms – including, of course, woody plants.

The photosynthesis of single-celled organisms living in the aquatic environment also became a source of large amounts of oxygen, which in its gaseous state constitutes today a volume of about 21% in the atmosphere. Oxygen is an element with a particular potential for releasing energy from the hydrocarbon bonds of organic substances, so the evolution of photosynthesis has created qualitatively new properties of biogenetic processes.

Photosynthesising monocytes have also become food for other single-cell organisms, and in the processes of endosymbiosis, they have transformed into the cytoplasmic organelles, chloroplasts and mitochondria of host cells (Kączkowski 1980; Kopcewicz, Lewak 2019).

The presence in the protoplasm of organelles with the enzymatic potential to synthesize and release metabolic energy with ATP initiated the specialization of structures of multicellular organisms, that is, plants and animals, in the ocean environment about 800 million years ago. Until the end of the Precambrian period, the property of both forms of life in this environment was, previously formed in single-celled individuals, the ability to replicate DNA molecular memory and reproduce by cell division with the possibility of mutagenesis and the evolution of the functional structure of offspring (initially multicellular backbone), and then by specialising in the properties of the cellular structure of tissues and organs. This stage of the evolution of life was also a period of the development of the physiological control of morphogenesis, assessment of the position of organisms in relation to food sources (e.g., solar radiation energy) and water, and the control of organ growth or movement to enable the realization of life functions. In these processes, the already functioning orientation system in single-celled organisms was also used, related to the mechanism of physiologically controlling the movement of protein channels regulating the exchange of protons and ions of phospholipid cell membranes.

For plants in water bodies, but also for terrestrial organisms, this is usually the direction of phototropism, and thus, it is the opposite direction of Earth's gravity. However, it is at the same time the direction determining, in accordance with the gravitational vector, the location of water sources on land and the direction of precipitation in the Earth's atmosphere.

The processes of plant growth polarization have been the subject of research by physiologists for many years, but it was only in 1974 that L.P. Jaffe and other American scientists (Wodzicki 1984) published research results proving the relationship between plant cell polarization and the influence of the gravitational gradient or solar light radiation on the basipetal direction of the ion channels in the embryonic phospholipid membranes of plant cells.

These results provided the basis for a discussion on the problems of polarization of cytoplasmic membrane structures in the process of meristematic cell division (Wodzicki 1984, 1988, 2001; Wodzicki, Wodzicki 1996). They also provided an opportunity to discuss the details of the process of organogenesis of terrestrial plants involving phytohormones (especially auxins), that is, the process of orientation of the 'root−crown' axis development and the differentiation of water conduction system in forest trees.

Almost each of the above mentioned phases of development of the structure of organisms is characterised by new properties. In the offspring of organisms that have experienced qualitative changes in structural properties, a period follows of testing various forms of expressing this transformation in the sense of increasing the effectiveness of physiological factors of the system's homeostasis. These are therefore the periods of development of variable populations and phylogenetic progress, which are the subject of various biological studies (Hejnowicz 1973, 2002; Kopcewicz 2016).

From reflections about the succession of qualitatively new properties in the evolution of life, which led to the development of body polarization and the settlement of plants on land, it follows that this was a process of the movement of protein channels in the cell membrane due to the exchange of ions, especially of hydrogen and calcium ions, between the abiotic environment and the interior of plant cells (Hejnowicz 1973, 2002), and especially in forest trees (Wodzicki 1984, 1988, 2001, 2004; Wodzicki, Wodzicki 1996).

To summarize, the basic condition for life on Earth is the supply of free energy (geothermal or sunlight) and access to a source of elements: carbon, hydrogen, oxygen, nitrogen and trace amounts of phosphorus, sulphur, magnesium, iron, calcium, sodium, potassium, iodine, and so on, and above all water. All these requirements are met by oceans and other permanent water bodies, but particularly favourable physical conditions for the development of life was found on land in a gaseous atmosphere (78% nitrogen and 21% oxygen) due to the abundance of solar energy and the evolution of the protein-chlorophyll complex of autotrophs.

Water occurs in the Earth's atmosphere in three forms – but permanently only in a gaseous form, thus, in a fraction of about a thousandth of a percent. The other two forms are water in a liquefied form as fog, clouds or rain, or in the form of crystalline snowflakes or particles of ice as hail. The size of the water droplets or the structural particles of ice (weight) determines their potential to fall to the ground. Still, however, the form and amount of precipitation is determined by the thermal conditions of the atmosphere, and is dependent on daily or seasonal variability and location in relation not only to the distance from the geographic poles of the globe, but also to the proximity of the oceans, the height of the atmospheric area above sea level, and even the relief of the terrain and direction of prevailing winds.

Photosynthetic plants can, therefore, obtain liquid water on land in principle (with small exceptions) only after it has moved from the atmosphere to the Earth's surface, where it is usually located in rock crevices, soil or finally flows with gravity into the water bodies of lakes, seas and oceans (a special case is ice water in regions with negative temperatures).

In order to take advantage of the possibilities of the efficient photosynthesis of autotrophic organisms in the Earth's gaseous atmosphere, all forms of life became dependent on the evolution of the functional structure of organs obtaining water in a liquid state, from the surface of the land.

Forest ecosystems on the surface of the land, whose structure is determined by the tree stand, are therefore the most important biological system, whose key property is the creation of a wide area forming an environment of life on land in the gaseous atmosphere of our planet. Only woody plants in the course of evolution have developed wood, that is, as secondary tissue, capable of ensuring the transport of water to the photosynthetic organs of the autotrophs on land, providing food for many heterotrophic terrestrial life forms.

This also applies to the root zone area of trees, which is a niche environment for the development of various vertebrate and insect species, but above all, for the existence of symbiotic thallophytes and soil microorganisms. To summarize, it is possible to determine the width of the photosphere of life as an area defined by the level of penetration of tree roots in the soil and the height of the stand, the upper limit of which can be considered even up to the height of the flight of the birds nesting in the forest.

3. The structure of wood tissue and emergent properties of the forest

In the Cambrian period (417–354 million years ago), first mushrooms, lichens and finally bryophytes appeared on land, in which the first elongated water-conducting cells (xyloids) were differentiated in the tissue system. However, they still had cytoplasm and did not form a secondary cell wall. Thus, they did not differentiate the elements of wood, which, after the autolysis of protoplast, functioned in higher plants as a tissue capillary system for conducting water from the Earth's surface, using the suction power of transpiring leaves and overcoming the resistance of gravity to supply the cellular apparatus of photosynthesis, located at a considerable distance from the ground water level.

Only some psylophyta, and later lycophytes, horsetails, tree ferns, cycadales, cordaitales, and finally, gymnosperms gradually developed the wood tissue (xylem), whose water-conducting cells, that is, tracheids and structural vessel elements, formed a lignified secondary cell wall and autolysed the protoplast.

The problems of xylogenesis have been the subject of many studies and publications (Hejnowicz 1973, 2002; Wodzicki 2001), but these are the results of research on the cambium, initiated by the British physician Nehemiah Grew in 1682 (shortly after the microscope was constructed in the Netherlands), which showed for the first time the cross-sections of water-conducting wood cells in tree trunks, which he called tracheids and vessels analogously to the nomenclature adopted earlier in medicine (Wood 1965). E.S. Barghorn (1964) – a paleobotanist and specialist in the evolution of woody plants – linked this event with a period of genetic mutation, which enabled the synthesis of lignin giving the secondary wall of wood cells the necessary rigidity of a duct to perform the conduction function.

In order to illustrate the scale of the problem of water conduction in forest trees in the process of transpiration, the results of a study on a single specimen of an old oak conducted during the 71 days of the growing season – by researchers at the Oxford Dendrochronology Laboratory, Forest Research under the direction of Prof. Graham Stone and Prof. Patrick Meir – were presented in the TV program *Da Vinci* (26.03.2020) by Dr. George Mc Gavin. A several hundred-year-old oak "drank" (as it was described) 68,822 litres of water as a result of the total effect of transpiration of 700,000 leaves and produced more than 230 kg of mass in the last tree ring.

In the course of evolution, different taxonomic forms of trees diversified the structure and transport potential of the cellular elements of wood. The earliest arrangement of tracheids connected by funnel-shaped cavities differentiates the oldest taxa of woody plants. The angiosperms (which evolved later) are differentiated by scattered vascular or concentric ring vascular types of wood, where the cellular elements connect either through a series of parallel straight cavities, or through an open ring creating a route for the complete hydrolysis of the transverse walls between vessel segments.

Actually, all types of conductive wood tissue are formed as a result of the activity of the secondary meristem of the cambium located on the perimeter of the tree trunk and branches, creating annual growth rings in accordance with the seasonal changes of climatic conditions in different parts of the globe at various altitudes above sea level. The result of these seasonal changes is the creation of annual growth rings, whose structure of early and late wood differs in terms of the radial diameter of the tracheids or the number, size and even the system of connections between the water-conducting cells.

The seasonal differentiation of xylogenesis is in all cases determined by the variability of water conduction conditions. This may be a seasonal change in the temperature of the soil (the source of the water), in atmospheric air limiting the suction force of water transpiration in the tree crown, or changing conditions in the cohesion of liquid water molecules and their adhesive ability, that is, the forces of water adhesion to the walls of the conductive cells, which changes the capillary potential of the wood cells.

In climates with little seasonal variation, for example, palms, the conductive tissue is formed in a bundle system due to the activity of only the apex meristem. For conduction to take place in the wood, water must be absorbed from the soil through osmosis by live root hairs (in forest trees, often with the participation of mycorrhizal fungi) and move further in the gradient of the osmotic value of the vacuoles in the parenchyma cells of the roots. It is then transferred by the root pressure resulting from this process to the wood cells. The force of the suction, creating negative pressure in the conduits of the wood cell water conduction system, also occurs as the result of an appropriately oriented gradient of the osmotic value of the soft tissue cells of the leaf stomata.

Thus, the evolution of water conduction in forest trees is the result of the interaction of many forces and processes controlled by the variability of environmental conditions and the interaction of the physiological processes of the cells, both the cellular systems of the exchange of gas in the crown as well as the root absorption system. The living organism of a woody plant has many forms of physiological reactions at its disposal, and thus, a significant potential to adapt its tissue system to changes in environmental factors, for example, such processes as the formation of thyloses in vessels, the isolation of embolism sites, the control of stomata functions or the regulation of the osmotic pressure of the vacuolar liquid of the root cells.

The aim of this study is mainly the theoretical justification for the formulation of the concept of a scientific definition of the emergent properties of the forest as the photosphere of life in Earth's atmosphere. Information from several fields of knowledge has been selected, reminding us at the same time about some of the mechanisms conditioning life on Earth, and especially about the evolution of water management processes of forest trees (Zimmermann, Brown 1981; Zimmermann 1983; Tulik 2012).

It is worth considering to what extent a property of the forest is the environment of life that initiated the evolution of *Homo sapiens* – because wasn't it the forest environment that created the conditions enabling the evolution of the mind to attain the state of self-awareness? This would also mean creating an environment for the evolution of humans' creative potential – a world of ideas and criteria for valuing intentions or impressions.

Current knowledge about the development of the universe allows us to think that this is a saltatory process of providing information about the functional potential of energy distribution in successively tested variants of the systemic structure. The direction is known, but what is not known is the sense and whether there are limits to the evolution of the universe (and thus, its stages). The last known evolutionary leap is the creation on Earth of the creative potential of energy metabolism in the universe with the participation of information transfer in trillions of specialised human brain cells and the creative potential of self-awareness, also possible as the result of the development of ever more perfect memory systems – from quantum and molecular memory to the genetic memory of life in general, and then the intellectual functions of the human brain and technical (but not only) cultural achievements. It seems that there are certain chances for successive future insight into the sources of the creative potential of information. The process of evolution is like conquering distance by marching on a road towards a goal – it takes place in steps of different lengths proceeding in different directions. Only some reach the distance, finalised by a leap, which improves how the journeys continued.

The discussion about the emergent properties of the forest, which is a niche ecosystem with the highest potential for energy management and its circulation in space, can also be an opportunity to comment on the philosophy of development. The choice of properties of the forest as a photosphere of life, not a hydrosphere, results from the fact that almost the whole heterotrophic part of the niche structure of forest ecosystems, drawing water mainly from surface reservoirs, on its own – without a tree stand – does not create the homeostasis of the spatial area of life in the Earth's atmosphere. In future, it is worth paying greater attention to how tree stands may shape the microclimate in the abiotic environment of forest ecosystems, for example, the influence of species composition or tree crown density on the level of moisture and the gas structure of air under the forest canopy.

To summarize, about 350 million years ago in the Devonian, when the first forests appeared, the ecosystems of woody plants on land created a vast photosphere of life in the gaseous atmosphere of the Earth. The expression of this property of forest ecosystems is a characteristic feature of every formation of forest structure regardless of the species composition, foliage morphology, crown shape or the scale of the height increment of the trees inhabiting different habitats, determined by the variability of structure, soil moisture and climate or location above sea level. Thus, the property of creating the photosphere by forests on land concerned and concerns today all known forms of forest ecosystems that have developed in every geographical zone of planet Earth.

4. The meaning of certain concepts

Archaea (singular archaeon) – primary non-nuclear monocellular organisms, whose chemical composition of the cell membrane, unlike that of bacteria, enables life at high temperatures. Genetic research in recent years has shown that they are more closely related to eukaryotes than bacteria (or eukaryotes may have even evolved from them). Their DNA is packed into nucleosomes whose core is formed by histone proteins. The genetic material is divided by introns. As chemo-autotrophs capable of reducing sulphur compounds, they were known as organisms living in extreme environments. Today, archaea living in moderate conditions are also known. Archaea are a separate branch of evolution from eubacteria.

Endosymbiosis −a physiological interaction when one organism lives inside the body of another organism to the benefit of both, and even conditioning the evolution of a new biological form. Endosymbiosis is a derivative of the evolution of symbiosis, and thus the interaction of an ecological form of the coexistence of organisms.

Embolism − synonyms: cavitation and aeration of vessels (Hejnowicz 2002) −the interruption of the continuity of water stream in the wood cell water-conducting system. This may result from air penetration due to tissue damage or the ingrowth of adjacent parenchyma cells into the xylem vessels or tracheids. Usually, the cause of embolism is when: 1) negative pressure exceeds the adhesion of water to the wall surface of the conductive wood cells; 2) sufficiently large gas bubbles, called gaseous embolisms, appear.

Conflicts of interest

The author declares the lack of potential conflicts of interest.

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