Environment and Social Psychology (2023) Volume 8 Issue 3
doi: 10.54517/esp.v8i3.1869

RESEARCH ARTICLE

Biophilia in pieces: Critical approach of a general concept

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ABSTRACT

The biophilia hypothesis is critically approached in the context of evolutionary psychology, adaptation of the sensory systems and application to sustainable and urban planning, namely in the field of urban green spaces. From an evolutionary perspective, our biophilic tendencies are generally accepted and interpreted as an adaptation to natural environments, where the ability to connect with, and understand habitats and other living beings, was crucial to our survival. This statement is critically addressed by the paper, through a narrative review, namely by discussing biophilia and biphobia as general and specific adaptations, with different learning properties. Nevertheless, research on the health effects of the perceptive systems points to special selected mechanisms internal to the general biophilic adaptation. Criticism of the biophilia hypothesis is explored. The paper concludes by pointing to the importance of urban green spaces, both for the development of the biophilic predispositions and for sustainability and regenerative approaches in the cities.

Keywords: biophilia; adaptation; sensory systems; criticism; ecosocial and regenerative urban planning; urban green spaces

1. Introduction

Research related to the biophilia hypothesis has grown in recent decades. Biophilia is a term composed of two Greek root words, bio meaning life, and philia meaning friendship, often also translated as love. Biophilia is, therefore, friendship or love for life, and the term was first introduced in western literature by the German psychoanalyst Erich Fromm in the middle of the 20th century. Fromm differentiated the biophilic

ARTICLE INFO
Received: 29 June 2023 | Accepted: 22 August 2023 | Available online: 12 October 2023

CITATION
Lencastre MPA, Vidal DG, Lopes HS, Curado MJ. Biophilia in pieces: Critical approach of a general concept. *Environment and Social Psychology* 2023; 8(3): 1869. doi: 10.54517/esp.v8i3.1869

personality from the necrophiliac personality who has a taste for the inanimate and mechanical, for what is dead[1]. Later, the term was taken up by Wilson[2], an American entomologist who described biophilia as the deep relationship that human beings have with nature. Wilson was interested in biophilia as an evolutionary adaptation to the living world. He assumed a phylogenetic approach and proposed a set of inherited learning rules for biophilia as well as for its opposite, biophobia[3].

Biophilia was mainly conceptualized by Fromm[1] as a psychological orientation, and his ontogenetic perspective was focused on the developmental conditions for the biophilic personality. Fromm's ontogenetic and Wilson's phylogenetic perspectives are not opposed, but are complementary to each other and, together, can produce research and refute more critical approaches to the biophilia hypothesis, which claim that the concept is vague and that the research associated with it does not justify its psychological or social scope[4].

Recent work goes towards showing that biophilia seems to be an interesting concept to deepen the relationship between health, sustainability and nature. Individual and social well-being, as well as the promotion of biodiversity in cities, urban cooling and oxygen production, CO_2 management and short food circuits are important arguments for the development of sustainable and biophilic green spaces in cities[5–8]. They meet the United Nations Sustainable Development Program[9] which, by 2030, plans universal access to safe and inclusive green spaces in cities, where the largest number of human inhabitants will be concentrated. The promotion of a global physical-mental health in the cities, and beyond, is also an important argument for biophilia research intersecting evo-devo lines of thought and experimentation. Studies of the development of the human brain have shown that exposure to natural environments during critical periods of development can have lasting positive effects on neural function and behaviour[10,11]. Therefore, the convergence of ecosocial and regenerative paradigms has ignited a profound reimagining of urban landscapes[12]. We believe that the principles of ecosocial and regenerative urban planning intersect with and are enhanced by the application of biophilic principles. While ecosocial urban planning emphasizes the integration of ecological sustainability and social equity into the urban fabric[13], regenerative urban planning is a forward-thinking approach to urban design and development that surpasses mere sustainability to actively restore and rejuvenate ecosystems and communities[14]. The integration of biophilia results in environments that that not only sustain ecological vitality but also fulfil our inherent need for a connection with nature.

This narrative review presents some of this research, questioning the biophilia hypothesis from the point of view of evolutionary psychology and its relationship with global fitness, traduced by improvements in health and well-being. Research will be presented on perceptive systems that will allow to assess the evo-devo importance of this concept. Criticisms of biophilia, and some research derived from it, are addressed in order to make it a more robust concept, both for theory and for application to socio-natural systems and future research. Finally, the paper will present the importance of urban green spaces for the development of biophilic predispositions and for social regenerative planning, by challenging the status quo, advocating for urban governance and policy framework that embrace biophilia.

2. Evolutionary psychology and the biophilia hypothesis

Evolutionary psychology thrives on the hypothesis that there is a human psychological nature, and that it is composed of a series of behavioural and mental adaptations to recurrent situations of the environment, typical of the evolution of *Homo sapiens*-c. 200,000 years before present[15]. Evolutionary psychology specifically considers the adaptations to late Pleistocene, where recent human evolution took place, but there are good reasons to accept that behavioural, emotional and cognitive adaptations came from further back in evolution and show obvious homologies with anthropoid primates and also with other mammals[16,17].

In evolutionary psychology, adaptation refers to the process by which traits or behaviours that confer a survival or reproductive advantage in a particular environment become more prevalent in a population over time. It has been applied to a wide range of psychological phenomena, including emotions, cognitive processes and social behaviours, with the idea that certain cognitive and social adaptations in humans, such as our ability to read facial expressions or our tendency to form coalitions, evolved in response to the adaptive challenges to complex social groups[15]. The idea that biophilia could be a cognitive and emotional adaptation was first proposed by Wilson] and since then, a large number of experimental research and surveys on the biophilic human proclivities were launched, and the hypothesis is generally accepted. In fact, as stated by Sussman and Hollander[18] setting out to control the environment is a hallmark of many species, not only human beings. Two recent meta-analyses of experimental studies on the emotional impacts of human exposure to natural and urban environments confirm the affective dimensions of nature exposure. McMahan and Estes[19] meta-analysis examined 21 studies and found that exposure to natural environments was associated with decreased negative emotions and increased positive emotions compared to exposure to urban environments. Twohig-Bennett and Jones[20] meta-analysis explored 33 studies and found that exposure to nature was associated with reduced stress and improved mood.

The concept of biophilia as a biopsychological adaptation involves several related ideas. These include the savannah hypothesis, which was proposed by Rabinowitz and Coughlin[21], Orians[22], and Balling and Falk[23]. Additionally, the prospect-refuge theory, introduced by Appleton[24], is relevant, along with broader concepts such as the stress recovery theory, as described by Ulrich et al.[25], and the habitat theory, also proposed by Appleton[24]. Restorative environments are another key concept, which draws heavily on attention restoration theory, originally proposed by Kaplan and Kaplan[26]. Attention restoration theory and stress recovery theory are grounded in an evolutionary perspective, and have a fundamentally biopsychological foundation.

Nevertheless, soon after the biophilia hypothesis was first enunciated by Wilson[2] stating that the positive relationship to nature is an adaptation, and therefore a universal set of emotional and cognitive traits, it was recognized that it is difficult to specify, and therefore difficult to refute[27]. We will focus on this issue, discussing if biophilia is an adaptation and examining it through the lenses of specific perceptive systems and their reactions to natural, and non-natural stimuli as a control. The approach draws on systematic pieces of research to experimentally test the biophilia hypothesis and a synthesis diagram is presented in **Figure 1**.

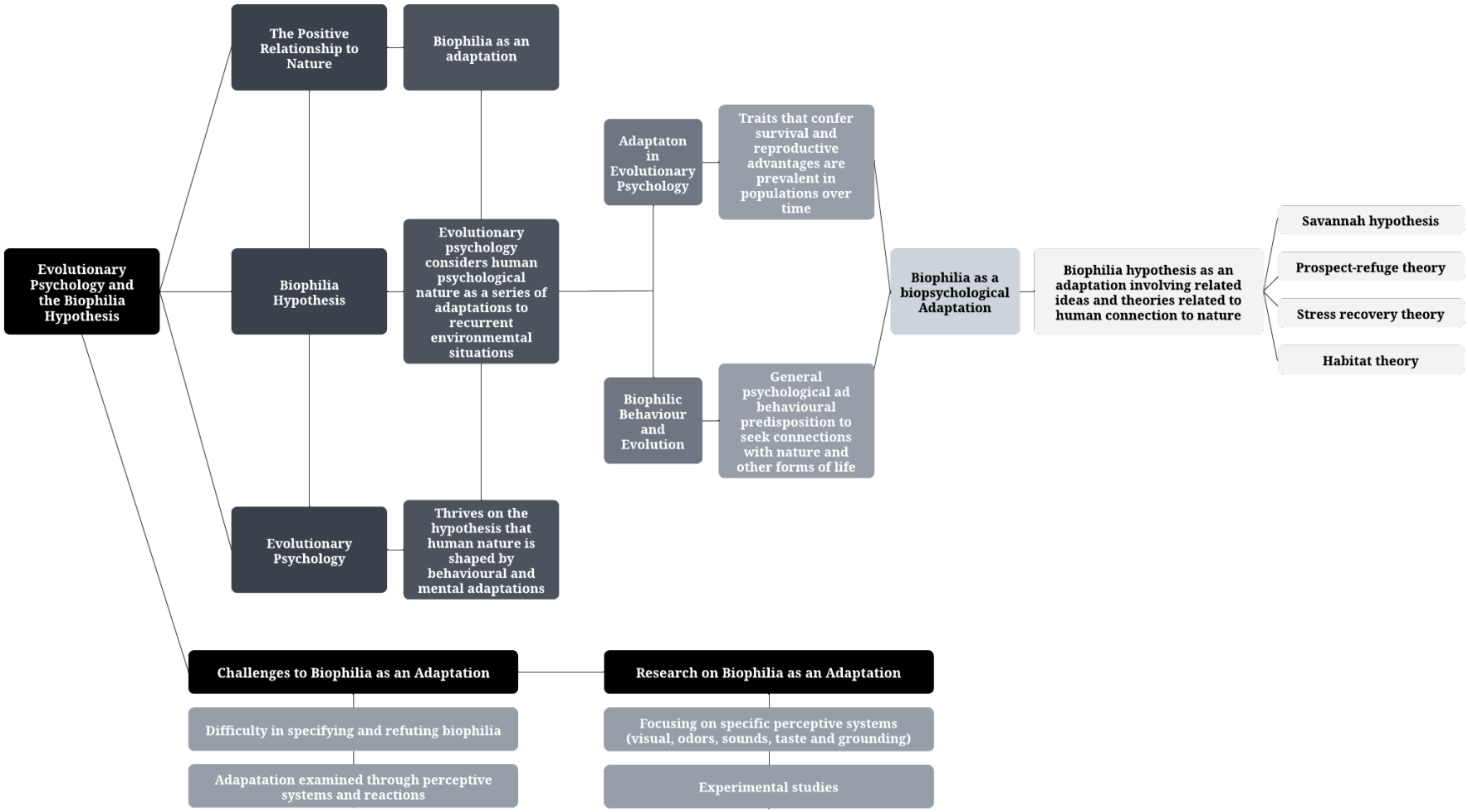

Figure 1. Synthesis of the main ideas about evolutionary psychology and the biophilia hypothesis discussed in the text.

2.1. Is biophilia an adaptation

Multi-level selection like natural, sexual or group selection[28] are generally accepted to have operated in evolution so as to define a set of physiological, behavioural and mental adaptations that are designated as evolved psychological dispositions[29]. These can be domain-specific, when they are adapted to solving specific survival and reproduction problems, or they can represent more general ways of acting and thinking, corresponding then to domain-general behavioural, emotional and cognitive dispositions. Examples of specific psychological dispositions are those that enable language acquisition, promote attachment and avoid incest, or those that help detect mistakes and deception. More general psychological dispositions are those that allow the learning of general social and cognitive skills. All these psychological dispositions are guided by learning, in a more or less specialized way, and are sensitive to critical periods during development, to contexts and to environments in which they occur[30]. Language, for example, implies exposure to the speaking community, just as attachment implies the presence of an attachment figure during the first few years of life. The avoidance of incest implies exposure to the family figures during a sensitive period[31,32], in the same way that, in a more open context to future learning, sexual preferences seem to be connoted at that time[33]. Taking into account current scientific evidence, it is likely that biophilia corresponds to a general psychological and behavioural predisposition that is characterized by specific internal adaptations where learning plays an important role during development[34].

Generally stated, biophilia refers to the human tendency to seek connections with nature and other forms of life. While some evolutionary psychologists and biologists argue that biophilia is an adaptation that evolved in response to the adaptive challenges of the Pleistocene[35], others have suggested that it is a byproduct of other cognitive and perceptual mechanisms that manifests themselves in our emotional, cognitive, and aesthetic responses to nature. There is evidence to suggest that our affinity for nature may be the result of more general cognitive and perceptual mechanisms[4]. For example, some researchers have suggested that our preference for natural environments may be the result of their visual complexity and the fact that they provide opportunities for restorative experiences. Others have suggested that our attraction to nature may be driven by our innate curiosity about the natural world and our desire to explore and learn about it[36,37]. Biophilia might be entangled with those systems through specific mechanisms that have developmental pathways to express themselves. Research indicates that young children may have a heightened sensitivity to natural stimuli. Wohlwill[38] for example, demonstrated that children as young as six years old were able to spontaneously categorize natural from human-made stimuli. Gelman and Markman[39] found that, in an inference task using different objects, young children considered more important to belong to natural categories, than to have perceptual similarities. Similarly, Atran[40] also found that adults' principles for categorizing plants and animals were consistent across cultures, further supporting the predisposition developmental roots of biophilia.

2.2. Biophobia as a specific adaptation

Biophobia seems to have a more evident behavioural and psychophysiological specificity than biophilia, and this characteristic may be related to the importance of a rapid adapted response to danger. The Garcia effect[41], for example, showed that rats associated nausea with taste, but not with other sensorial stimuli like touch, thus pointing to the adaptive quality of the response. Specialized fear learning adaptations are common among primates. For example, if a monkey observes another monkey showing a fearful reaction to a snake, it will quickly learn that same fear[42]. However, if the other monkey has a fear response to flowers, he will not learn that fear response. The fear of snakes, once learned, is unlikely to be extinguished[43]. The reason for these differences in learning and memory relates to the real danger that snakes presented in the evolutionary past, whereas flowers are generally not dangerous. Biophobia thus designates an intense fear of one or more natural elements that seems to be biologically prepared by evolution. This fear can be of animals (zoophobia),

closed environments (claustrophobia), open environments (agoraphobia) or the sight of blood (hemophobia), for example.

A psychological disposition like biophobia is related to a small range of information, helps to solve a specific survival problem and can be an adapted physiological, behavioural or mental response, thus corresponding to the definition of a specific adaptation[15]. Hemophobia, or fear of blood, for example, leads to fainting with bradycardia and a sudden drop in blood pressure, making bleeding less likely. Through an adapted reaction, the organism increases its chances of survival, since the sight of blood usually corresponds to an open wound, in a predator environment that, in the past, could be dangerous. Immobility, fainting death, generally disperses predation[44]. Similarly, claustrophobia prevents being trapped in closed spaces, and agoraphobia prevents exposure in open spaces, visible to aggressors.

2.3. Biophilia as a general adaptation

The biophilic behaviour does not have the same specificity as biophobia behaviour. The explanation may be related to the fact that, during his evolution, *Homo sapiens* lived 99% of the time as a hunter and gatherer in changing natural environments, having become an urban inhabitant only very recently[2]. For this reason, natural selection acted generically on the preference for large environmental traits, which allowed for a good regulation of the relations between the organism and the environment. Like today, attention was generally captured by the likely affordance of food resources, refuge, vigilance and interesting events[45]. These latter are the general characteristics of habitats like the tropical African savannah, where the evolution of *Homo sapiens* mostly occurred. And it is precisely the preference for these traits that we generally find in the results of studies on the savannah hypothesis, with quick and unequivocal emotional responses by the participants[46]. Landscapes with water points, places of shelter and surveillance, wide plains and groups of trees with medium canopy, are the preferred landscapes, cross-culturally[47]. These landscapes correspond currently to the basic plan of urban parks with spatial opening, groupings of trees and presence of lakes. Deserts, dense forests or modern constructions are environments least chosen by study participants[26]. It is important, however, to mention that other studies have shown a preference for landscapes with very green vegetation, and equally influenced by people's familiarity with the environment where they developed and live[48]. The preference for green, instead of the more characteristic yellow of the savannah, could be understood as the perception of water, meaning the presence of food. Preference for familiar landscapes, even urban ones, could relate to safety and refuge perception. These, and other critical methodological characteristics of the natural preferences, namely related to prepared learning and culture, suggest that the savanna hypothesis should be subject to further research that tests specific aspects of evolutionary prepared learning of perception, and behaviour in material spaces.

It is likely that the preference for natural elements needs learning in sensitive periods, and ontogenetic studies focusing on specific perceptual traits have a lot of methodological interest in this context. Similarly, epigenetics has shown that the intergenerational transmission of experiences can affect the preferences and avoidances of subsequent generations. This type of acquired, and reversible, inheritance is achieved through DNA methylation or through the modification of histones. Biophilic predispositions may have been transmitted this way. DNA methylation and histone modification are conditioned by natural selection and make the organism fit for specific ecologies. As ecologies tend to change overtime, seasonally and over longer periods of time, resilience and learning have an important role for adaptation. Biophilia, as a general, open adaptation, may have acted as an ontogenetic mechanism to changing environments, within limits, stabilizing itself as a physiological and mental trait during evolution. These limits to adaptation may depend on the micro-mechanisms that have a more stereospecific response to natural stimuli. While there is an adaptive plasticity of the whole relationship to the environment, there might be more specific internal mechanisms that show a

deeper stereospecificity to natural elements. Thus, calibrating mechanisms of specific and plastic adaptation are evidence that the organisms have moved between changing and varied environments that they eventually choose. They are some kind of adapted preference generalists[49].

To test these ideas, the following points will present some specific research on biophilia as an adaptation, focusing on the perceptive systems such as the visual perceptual patterns, odours and sounds, taste and grounding. This research allows to either to refute or accept the hypothesis of biophilia, because it focuses on special features of perception in relation to natural elements that can be operationalized. These studies tend to corroborate the hypothesis of biophilia as an adaptation, by showing how fine-tuned features of perception tend to maximize the organism's fitness and adequation to the environment and other species, thus promoting health and well-being. As we will see in this paper, these fine-tuned features correspond to smaller micro-mechanisms of the general adaptation that show a stereospecific response to natural stimuli.

Biophilia as a general adaptation allowed us to dwell in concrete artificial ecosystems like the crowded cities where most of us live, or to forage in shopping malls, away from natural habitat and resources. Nevertheless, it is the health and well-being effect that proves the importance of the natural settings for current human adaptation, contrary to the artificial environments that have the opposite effect, namely on the brain and on mental health[50].

3. Biophilia in pieces: Some evidence from perceptive systems

3.1. Visual perception of natural forms

Finer investigations on the evolution of sensory-motor adaptations to the environment have indirectly highlighted some interesting aspects of biophilia. Research that didn't grow primarily from the field confirmed that biophilia results in fine-tuned perceptual adaptations to the natural world that help navigate it in good organic conditions. Research using eye-tracking and brain techniques examined people's gaze patterns and brain activity during a visual experiment, and the results indicate that they prefer, and respond specifically, to certain forms found in nature.

Pupils have a fractal search pattern, from the largest to the smallest frame, and fractals are repetitive structures that are found abundantly in nature. Based on his work in the neurophysiology of perception, Taylor[51] considers that there is a specific affinity between the brain and these frequent forms of the natural world, which would explain not only the fascination effect produced by the perception of natural forms, previously described by Kaplan[52], but also the relaxation effect of directed attention, and also the perceptual fluency effect. This research, initially oriented towards the study of fractal perceptual patterns in art, resulted in a broader application to fractals in nature, also extending the original concept to design in urban architecture. In urban landscapes, people risk disconnecting from natural stress-reducers and be captive of concrete, static and monotonous forms. This study show that it is much cheaper to invest in nature prevention, than to invest in heavy and anxiogenic treatment infrastructures, such as hospitals. The design of biophilic cities with varied and accessible green spaces, where people can enjoy the vision of natural patterns, is an important investment in public mental health. This has been explored by Lavdas and Schirpke[53] that found that the prominence of a naturally unfolding hierarchical pattern and the inclusion of fractal visuals or intricate, pre-modern edifices, consistently held a superior appeal compared to alternative approaches.

3.2. Shinrin-yoku and odour perception

Other research was devoted to studying the relationship of sensory channels other than vision, with nature. The sense of smell has been particularly deepened by the Japanese school of Shinrin-yoku, or forest bathing[54–56]. Japan has a long historical and spiritual tradition of connecting with the natural elements, and plants have

very special meanings in that culture. The art of flower arrangements and the conceptions of Shintoism and Buddhism that the divine is inscribed in the landscape, shows that nature is not conceived as separate from humans. There is a need for both to be in a harmonious relation, which is tangible in the configuration of the gardens and houses where the inside and the outside are in material and symbolic relationship.

Research on the effects on health and well-being of walking in natural settings, or simply being in the forest, began in the 90s of the last century, and has demonstrated a range of benefits such as lowering blood pressure, improving sleep, controlling stress, improving mood and strengthening the immune system[57]. The hypothesis raised by Li[57] to explain the increase in anti-cancer white blood cells, after a 3-day stay in the forest, is that the chemicals exhaled by the trees, called phytocides, affected the immune system through smell.

There are different types of phytocides, and the biggest producers are evergreen trees, such as pines or cypresses. The main components of phytocides are terpenes, such as D-limonene, alpha-pinene or camphene[57]. Li[57] incubated immune system cells with phytocides for several days and found that their activity increased when exposed to cancer cells. Another experiment by the same author showed that spreading Japanese cypress oil, for three nights, in rooms where 12 healthy men slept not only positively affected the functioning of the immune system, but also increased the hours of sleep, reduced stress and improved mood[57].

On the other hand, Chen et al.[58] examined the effect of Japanese cypress Meniki and Hinoki essential oils on the activity of human autonomic nervous system. Blood pressure and heart rate of the participants were decreased, as well as the sympathetic nervous activity. Parasympathetic activity and heart rate variability were increased, and both Meniki and Hinoki wood essential oils stimulated a pleasant mood state[58]. These experiences, and others, reinforce the idea that aromatherapy with essential oils can improve the body's general state by strengthening the immune system and by improving mood. The destruction of our forest ecosystems means that we deprive ourselves of those important substances and of simple recipes for general health and well-being.

It is important to add that odours have an important cultural component and the learning of smells, from intrauterine life on, influences preferences for different perfumes and tastes. Rowe[59] widely described the influence of the odours of his childhood in the literary work "À la recherche du temps perdu". The reason why a scent can strongly evoke emotions and memories is because the hippocampus and the amygdala, important brain regions involved in memory and learning, are stimulated by smell. Odours have a powerful evocative imaginary effect that probably articulates phylogenetic, epigenetic and ontogenetic information. Recent experiments with mice have shown that the experience of avoiding a negative olfactory stimulus by the father of rats, was transmitted to offspring through sperm DNA methylation[60]. Olfactory and emotional information from parental experience was recognized without any prior exposure, or learning, by modelling or reinforcement. The offspring's brain showed an increase in the density of the pathways involved in odour perception, showing that in this primitive sense there is an important component linked to learning and intergenerational transmission of smell and also acquired trauma[61].

3.3. Sound and music

One of the most serious problems of cities and, in general, of the current world, is the level of noise generated by human activities[62]. It's hard to find a place where you can't hear a plane passing by, the distant noise of a car or of a construction work, nearby. The last century, and this century have witnessed an increase by about 30 decibels in the background noise, and this loud soundscape created by human activities was coined the anthropophone[63]. Noise is one of the most stressful environmental factors and, even during sleep, the autonomic nervous system reacts to the sounds produced by planes, cars and trains, increasing the heart rate, breathing and blood pressure[64]. There is an evolutionary reason for this ancient subconscious vigilance to

sounds during sleep: a predator or some other life-threatening event may suddenly rise in the night and being in a state of vigilance may have influenced survival and transmission of this reactive vigilance.

Audition evolved in fishes through sensitive vibratile hair cells, and the human fetus hears before he can see. Sound waves resonate throughout our body and stimulate the brain limbic system, responsible for emotions, before attaining the frontal cortex, where information is interpreted. So, our first reaction to sound is emotional and the alert state is positively correlated to noise, impacting mood, chronic stress and the immune system[63].

Hearing is essential for discriminating the quality of sounds coming from the environment, and also for communication. Not all sounds are stressful, and research has found that some natural sounds have quite the opposite effect. Alvarsson et al.[65] tested their subjects by exposing them to situations with sounds from nature, and with sounds from noisy environments, after they had resolved a stressful mental arithmetic task. The results showed that natural sounds facilitated physiological recovery from sympathetic activation after a psychological stressor[65]. The Acoustical Society of America presented in 2015 a number os studies showing that the sounds of nature not only impact positively our mood, but also improve our productivity and workplace satisfaction[66]. Indeed, people are sensitive to sounds ranging between 2500 and 3500 hertz and this is the sound range where birds sing and pleasant music resonates[57].

3.4. Contacting the earth

Geological science has demonstrated that the earth is characterized by a subtle electrical surface where free electrons, powered by solar energy and by lightning, can affect the body that naturally absorbs these particles. There is growing evidence that the earth's negative charge contributes to the internal stability of the bioelectrical environment of the living body[67]. Grounding, or walking barefoot on the grass or on the beach, simply lying down on the surface of the earth, these are all processes by which the negatively charged electrons enter the body and neutralize the free radicals, which are positively charged and cause different kinds of bodily inflammations. Grounding has the effect of naturally balancing the bioelectric circuitry between cells, and that process is beneficial to human and non-human systemic health[68]. Biological clocks that regulate natural rhythms like the diurnal or circadian rhythms, may be dependent on the oscillations of the intensity of the earth's electrical potential.

Non communicable diseases like auto-immune conditions, cardiovascular or respiratory diseases, mostly correlated with unhealthy behaviours, can also be understood as an "electron deficiency syndrome"[69]. This syndrome is characteristic of modern urban lifestyle with indoor insulation and intensive electromagnetic exposure through digital devices and through work environments. "Electron deficiency syndrome" is generally overlooked, and recent research has shown that it can be responsible for a number of important health disorders[67]. Grounding, or earthing, can function as a preventive lifestyle strategy and can have an anti-inflammatory effect, because it promotes the natural interchange of positive and negative electrons between the body and the earth's surface.

Although grounding is currently under-researched and is scientifically under-studied, there is growing evidence that electrical conductivity of the body functions as an immune system reinforcement and may have antioxidant effects[69]. There is also some evidence that grounding contributes to cardiovascular health. One study showed that grounding reduces blood viscosity, which is an important cause of the disease of the heart[70]. Another study measured the effects of grounding patches and mats on muscle pain levels, white cells number and levels of creatine kinase. When elevated, this latter means that there is muscle lesion. The results showed that grounding reduced levels of creatine kinase, white cells number, muscle damage and pain, suggesting that it possesses healing abilities[71]. Grounding has also positive effects on mood improvement, stress, depression

and fatigue[72]. Of course, all these conditions may have medical implications in need of special health care; grounding should be conceived as a complementary therapy.

3.5. The taste of nature

Taste is hardwired by natural selection into a complex circuitry that goes from the sensory receptors in the mouth, to specific regions of the brain and other unexpected body receptors distributed throughout the airways, stomach, intestine and pancreas. Here, the basic taste receptors of sweet, bitter, salt, sour, umami (glutamate), and probably some others, influence appetite and calibrate insulin production, thus regulating digestion and body weight[73]. They also influence respiration and even sperm maturation (ibidem). It is thought that the way taste receptors work, and influence taste preferences, promotes survival: not only do they detect and help appreciate nutritious foods, they also help avoid toxic ones and even identify harmful air and nasal compounds, inhibiting their inhalation deeper into the lungs[74]. Of course, the subjective experience of the activation of taste receptors in the intestine or airways is not comparable to the perception due to taste receptors in the mouth; they have different physiological and psychological functions and use different chemoreceptor systems (ibidem). But together, they contribute to an optimal body functioning, even if there is still little research on how tasting influence overall bodily health.

Taste preferences have been traditionally interpreted as promoting fitness and health. Preference for sugar, salt and fat, although being responsible for modern pathologies like diabetes, high blood pressure and cardiovascular disease, motivated the intake of rare foods dating back to the origin of our species. Cellular functions depend on salt intake, sugar is essential for the energy of physical and mental activities, and fat mostly characterizes the mass of the brain[75]. Unfortunately, these same elements are now present in a vast array of foods and contribute to enhance the taste of otherwise unattractive and unhealthy dietary. So, it is urgent to explore and promote consumer's preference for naturalness in food intake, like having the information about the properties of the food, the food origin and the way it has been produced[76]. The "Kampffmeyer food innovation study", another earlier study involving over 4000 consumers in eight European countries showed that naturalness is an essential trait for buying, and a big majority of the participants related natural to healthy food[76].

4. Critical appraisal of the biophilia hypothesis

As we saw above, the concept of biophilia has been subject to some criticism. Romanticizing our relationship to nature is one of those criticisms, arguing that research in biophilia ignores the complexities of the relations between humans and the environment. We know now that part of the biophilic motivation lies on early attachment to natural elements and that, if there is indeed an innate predisposition to prefer some natural stimuli over others, non-natural or natural (e.g., biophobia), this predisposition must be facilitated by exposure and experience. What we know by early studies is that the learning process is easier in natural contexts, and by, and for, natural elements. Children's play outdoors take different gender and group constellations than indoors, and is also more vigorous[77]. This research has shown that boys are more likely to engage in rough and tumble play outdoors, while girls tend to participate in more cooperative play and imaginative play scenarios. This is likely due to ethological dispositions articulated with societal expectations and gender norms that influence how children play and interact with each other[17].

Other critics argue that the biophilia hypothesis does not sufficiently consider theoretical approaches, such a social psychology, and does not include influences other than nature in shaping personality and social relationships[78]. This criticism can be easily tackled if we think about Fromm's work on necrophilia where, by opposition to biophilia, he states that this latter depends on a balanced early development of positive affects

towards nature and others[1]. If there is a biophilic predisposition, learning must activate and reinforce it during development.

Criticism of the innate version of the biophilic restorative hypothesis asserts that restoration by nature can be easier understood by testing the processing fluency hypothesis[78]. This hypothesis states that our liking of something is directly linked to how easily our brains process it in terms of thinking what it is, and understanding what it means. This perceptive and cognitive process is generally accompanied by positive affect, because fluency means that there is sufficient brain resources and efficient stimulus processing to deal with certain stimuli[79]. Of course, we can argue that the ultimate cause for the frequency of the fluency process in natural settings is precisely fine-tuned adaptations to these natural environments, because we evolved there for most of our evolutionary life. The research on fluency processing shows that cognitive restoration by unthreatening natural scenes are affectively more positively evaluated than by unthreatening urban scenes[78]. This is so because our visual system more fluently processes aspects of natural environments, rather than of built environments[80] and this can be attributed to evolutionary adaptive reasons. Redies[80] argues, as others have argued above in this paper, that natural scenes are characterized by fractal scaling properties that regularly appear, and that they elicit sparse visual coding to optimally process the statistical properties of natural stimuli. For him, this resonance is based on the adaptation of the visual system to natural scenes during evolution, and its non-intuitive character to cognitive introspection is dependent on the pregnancy of the form, rather than of the content, of the stimulus. This means that the perception of the natural stimuli is directly processed by the visual system without the need of cognitive inspection.

Another criticism is that the biophilia hypothesis is too abstract and difficult to define and evaluate. Some critics question the scientific validity of the theory of biophilia, arguing that the empirical evidence is inconclusive and that there is a lack of rigorous studies demonstrating the existence of an innate universal connection between humans and nature[4]. Our paper tries to answer to this criticism by showing that perceptual, cognitive and affective facilitation by natural elements can be independently examined by studies that approach distinct aspects of the biophilia hypothesis.

Other critics of the biophilia hypothesis point out that ignoring intersectional cultural influences such as race, ethnicity, class, and gender is a major flaw. According to these critics, biophilia presents itself as a universal and transcultural trait but, as we saw above by considering the learned aspects of the concept, the innate stance is not entirely accurate. These critics argue that, in general, the biophilia hypothesis fails to consider cultural and social factors that affect the relationship between humans and nature. Research has shown that people from different ethnic and cultural backgrounds have different attitudes and behaviours towards nature. For instance, African Americans and Hispanic Americans have been found to have a stronger connection with nature than white Americans. This could be due to their cultural backgrounds, which emphasize the importance of nature in their daily lives[81]. Other research has shown that subjective socio-cultural experiences influence environmental attitudes, like conceptions in environmental justice[82,83]. Studies indicated that low-income populations and black communities are more exposed to environmental injustices and hazardous pollutants, which leads to negative attitudes towards nature. This contradicts what would otherwise be a natural desire to live close to nature. Therefore, economic background can influence ecological preferences, and the intersection between racial identities and social class reinforces each other. Environmental racism not only worsens health and well-being outcomes, but also affects human-environmental relationships. The biophilia hypothesis should be more studied in these populations and their environments.

5. Biophilia, well-being and urban ecosocial regenerative planning

Recent research suggests that the concept of biophilia holds promise for fostering a stronger connection between health, regenerative planning, and nature[84]. Since ancient times, the presence of nature in urban spaces has been important for human well-being. But it was in the first half of the 18th century that, in England, the theme of nature took on a major role, giving rise to the emergence of informal gardens, breaking the renaissance tradition with formal garden designs[85]. The consequence was a change in thinking the urban and social behaviour, assuming the desire to recreate the countryside, the rural areas and nature in the urban environment. In the period after the First World War, due to the need to rebuild cities and to public health concerns, the search for elements and references to nature were essential for the creation of green spaces, considered fundamental for the quality of life of populations.

The relationship between the environment and human health is intrinsically linked to the definition of health, which, according to WHO[86], is "a state of complete physical, mental, and social well-being, and not merely the absence of disease or infirmity". This broad interpretation also encompasses elements of physical and psychological well-being, which can be shaped by positive emotions (linked to improved quality of life, life satisfaction, a sense of community, and the experience of happiness) as well as the reduction or absence of negative emotions (like anger, loneliness, or confusion)[87,88]. Being in nature promotes physical activity and supports a healthy lifestyle while minimizing the risk of various modern diseases related to urbanization (e.g., obesity, mental health problems, stress, etc.). Healthy activities related to nature, which can take place in urban spaces, include not only sports and physical exercise but also activities like gardening (for those who plant or take care of plants, flowers, and vegetables) for non-commercial use, as well as activities in home gardens (including community gardens)[89].

Regenerative planning goes beyond sustainability and has a holistic approach to socioecological systems (SES)[90], namely urban SES, by proposing a design of human systems that can coevolve with nature[91,92]. When applied to regenerative green spaces, this approach emphasizes the importance of incorporating design elements that enhance people's contact with nature through a co-creation process involving citizens. The co-creation of regenerative green spaces is viewed as a means to foster inclusive and equitable cities[14]. The development of sustainable and regenerative green spaces in urban areas offers numerous benefits, including improved individual and social well-being and physical health[93], the promotion of biodiversity, the mitigation of urban heat island effect, increased oxygen production, effective management of CO_2 emissions, and support for local food systems[94].

Natural assets in urban areas can act as effective carbon sinks and contribute to mitigating climate change-induced disasters. Therefore, biophilic urbanism represents a more integrated response to complex urban problems associated with climate change, offering an effective approach to ensuring urban sustainability and resilience. Additionally, the inherent salutogenic effects of nature on human health are evident. This connection, beyond fulfilling fundamental human needs such as food and natural resource supply, contributes to the prevention and alleviation of various diseases, making it a valuable health resource that generally promotes well-being[87,95]. The recreational and therapeutic value of nature for physical health and mental well-being has long been a topic of discussion, as demonstrated in this paper, and should not be overlooked within this holistic nature-human framework.

These objectives are in line with the United Nations' sustainable development goals, highlighting the significance of integrating nature into urban environments. Attending urban green spaces has also clear benefits on mental health[8] and pro-environmental behaviours[96]. Nisbet et al.[97] showed that the amount of time individuals spend in green spaces, and the frequency of their contact with nature, have an impact on their sense

of belonging, as well as their pro-social and pro-environmental behaviours. These latter refer to actions that aim to minimize negative impacts and enhance positive impacts on the environment. Conversely, a lack of proximity to nature has the opposite effect, leading people to seek out natural spaces less frequently, even if this detachment has detrimental effects on their mental health.

As we saw earlier in this paper, in his seminal work on biophilia, Wilson[2] proposed that the love of nature is not an innate mechanism with an immediate response, but rather a learning process, likely influenced by early imprinting and guided by genetically predisposed preferences and aversions. If this proposition holds true, it emphasizes the importance of early and ongoing exposure to natural environments in shaping individuals' affinity for nature. This perspective provides a compelling argument for urban planners to incorporate parks and gardens within cities, ensuring that residents have access to green spaces in walking distance, and throughout their lives. According to our previous exploratory research on the biophilic behaviour of a Portuguese sample in urban green spaces[8], there is a tendency to sense a strong connection with nature by the individuals that recurrently use urban green spaces. The surveyed users tend to prioritize green spaces that offer quiet and shaded areas, along with a diverse range of plant species that promote tranquility. Our study also revealed that satisfaction with urban green spaces positively influences self-perceived health status. This suggests that meeting users' expectations and providing satisfying green spaces can contribute to improving well-being in urban areas. Additionally, our research showed the enjoyment of nature and the perception of health and well-being are associated with pro-environmental behaviours, leading to the conservation of natural resources[8]. Following this, we proposed a new model of biophilic and ecosocial regenerative planning (**Figure 2**).

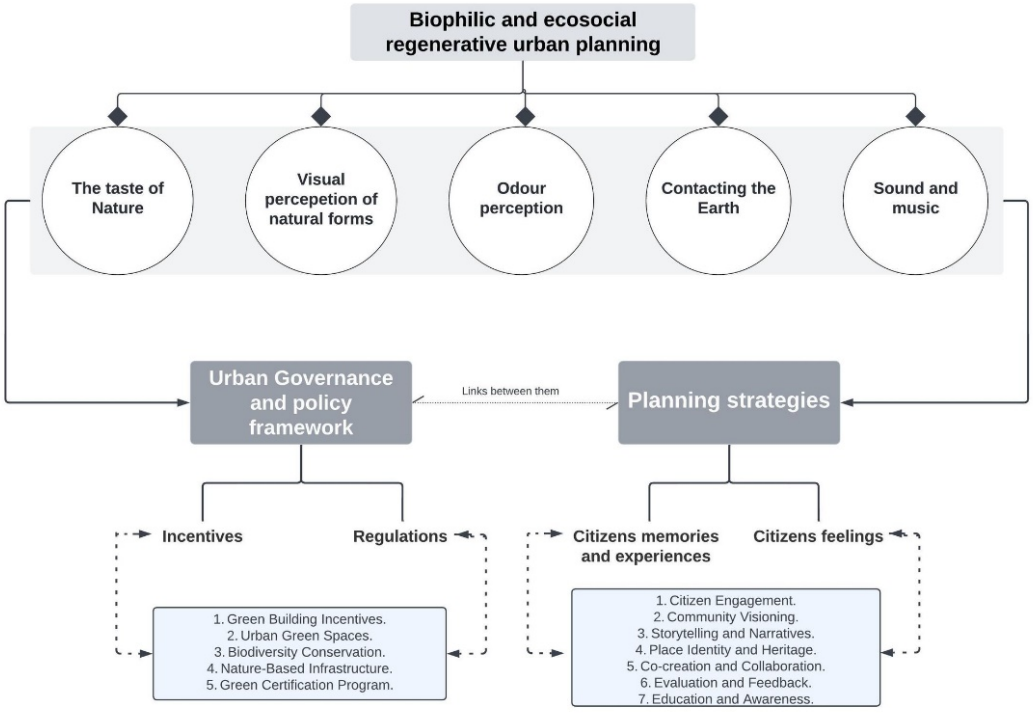

Figure 2. Biophilic and ecosocial regenerative planning proposed.

Urban design and management should actively foster biophilic predispositions and experiences, as they play a crucial role in shaping behaviours and attitudes[84]. By embracing biophilic principles, cities can create environments that promote the development of these connections with nature. This approach is supported by ample evidence demonstrating the positive impact of biophilic experiences on individual health and ecosocial

well-being. Innovatively, the integration of biophilic design and management strategies can go beyond mere aesthetics and incorporate elements that facilitate meaningful interactions with the natural world. By incorporating green spaces, natural elements, and sensory stimuli into urban environments, cities can provide opportunities for individuals to engage with nature on a regular basis. Such experiences have been shown to enhance physical and mental health, foster a sense of belonging, and promote overall well-being. By recognizing the importance of biophilic predispositions, urban planners and policymakers can prioritize the co-creation of ecosocial habitats within cities that enhance biodiversity as well as social well-being. This approach not only benefits individual residents but also contributes to the broader ecological balance and sustainability of urban ecosystems. Furthermore, revitalizing the human-nature bond requires revisiting educational policies and lifestyle practices for nature integration, reforming urban planning laws for biodiversity, and adapting transportation networks for better access to natural areas-prompting vital structural adjustments with profound impacts.

Embracing and promoting biophilic predispositions through urban design and management practices can create healthier, more liveable cities, since when ornamentation harmonizes seamlessly with a structure's entirety, it forges a connection between individuals and their surroundings, thus cultivating a positive and curative ambiance[98,99].

6. Conclusion

This paper aims to explore the biophilia hypothesis by emerging with a synthesis of insights that bridge evolutionary psychology, perceptive and socio-natural systems research and design. The intention was not to provide an exhaustive review, but rather to present some of the landscape of biophilic understanding and to shed light on innovative paths that extend beyond the established boundaries of the concept.

An important component of this paper was the fact that we have scrutinized the biophilia hypothesis, teasing out its profound connection to the intricate tapestry of overall fitness. The tapestry, woven with threads of health and well-being, is intricately tied to our innate affinity for the natural world. It is this affinity, rooted in our evolutionary history, that beckons us towards a renewed appreciation of our biological heritage. By addressing the main criticisms of biophilia and by discussing related research it was possible to enhance the robustness of the concept, both in theory and in its application to socio-natural systems and future investigations.

Amidst the theoretical contemplation, we have illuminated the vital role that urban green spaces play in nurturing our innate biophilic tendencies. These spaces, often overlooked in their significance, emerge as catalysts for regenerative urban planning. Our synthesis underscores the imperative of weaving biophilic principles into the very fabric of urban design. Not merely as an afterthought but as an integral thread that shapes urban environments into sanctuaries of natural harmony and social well-being. Yet, our contributions extend beyond theoretical discourse; they demand decisive action. We challenge the status quo, advocating for urban governance and policy frameworks that embrace biophilia. The call is not just for regulations, incentives, and planning strategies, but for a transformative integration of citizens' memories, experiences, and emotions. Weaving their narratives into the landscape design offers a bridge between human needs and spatial elements, cultivating a more profound connection to the environment.

The innovative core of this paper emanates from its integration of diverse disciplines, paving the way for a more holistic understanding of biophilia's essence. Our critical inquiry is not an end in itself, but a stepping stone toward creating urban landscapes that mirror our evolutionary heritage. As we cast our gaze toward future horizons, the endeavour shifts towards understanding how various biophilic methods can find their place

within urban environments of diverse scales. From the intimate corners of a building to the vast expanse of a region, this journey beckons us to transform our cities into living testaments of our innate connection to nature.

In conclusion, this paper does not merely summarize the biophilia hypothesis; it elevates it. It enriches the discourse, questions assumptions, and provides a roadmap for those dedicated to forging a harmonious coexistence between humanity and the natural world within the urban landscape. As we journey forth, may our urban landscapes evolve to reflect the intricate symphony of life, wherein biophilia transcends theory and becomes a guiding principle that shapes the very essence of our cities.

Author contributions

Conceptualization, MPAL, DGV, HSL and MJC; methodology, MPAL; validation, MPAL, DGV, HSL and MJC; formal analysis, MPAL, DGV, HSL and MJC; investigation, MPAL, DGV, HSL and MJC; resources, MPAL, DGV, HSL and MJC; writing—original draft preparation, MPAL, DGV, HSL and MJC; writing—review and editing, MPAL, DGV, HSL and MJC; visualization, MPAL, DGV, HSL and MJC; funding acquisition, MPAL and DGV. All authors have read and agreed to the published version of the manuscript.

Acknowledgments

The authors thank the Fundação Ensino e Cultura Fernando Pessoa (FFP) for the support of the project "Compor mundos: humanidades, bem-estar e saúde no século XXI". The authors would also like to express their gratitude for the important comments and suggestions from the editors and reviewers that contributed to improving the quality of their work.

Conflict of interest

The authors declare no conflict of interest.

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