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# Biomimetic approaches to color formation in ecological architecture

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**Abstract.** The article discusses the characteristics and features of the color formation in nature for solving problems of ecological architecture. The analysis of the main directions of research on the significance and possibilities of color solutions in creating an ecologically sustainable urban environment is presented. It is proposed to use analogs of nature to obtain natural features and qualities of ecological design of buildings, including in the formation of the color structural component of the design. As a result of the analysis of the studies, the mechanisms of color formation in nature, based on functional expediency, adaptation to the conditions of life in the environment, have been identified. The mechanism of formation of pigment, structural and combined colors in nature is considered. On the basis of the presented analysis of the functionality of color formation in nature, coloristic means of regulating the energy-efficient and environmental parameters of the building, namely thermoregulation, regulation of illumination, humidity, are identified. The examples of color solutions of building finishing aimed at adaptation to external environmental conditions are analyzed. The methods and possibilities of forming the color structure on the basis of the studied natural analogues for solving the problems of modern ecological architecture are systematized.

## 1. Introduction

After a period of dominance of purely technical solutions at the present stage of architecture development, more and more attention is paid to ecological design, the purpose of which is to create healthy and comfortable living conditions for a person while reducing energy costs and environmental impacts. The predominantly artificial objective environment of a modern city requires a return to design compatible with the environment, climate, that is, ecological design.



In total, in modern design, actual original spatial-shaped concepts are associated with new trends and stylistic directions, and, most importantly, with the development of new technologies. The reference to biological examples that inspire engineers to create new materials and technologies is based on the assumption that over billions of years of evolution, nature has created optimal living structures that are superior in efficiency and durability to man-made structures [1, 2].

Biomimetics is a design direction based on the reproduction of ideas from nature into constructive and technological solutions [3, 4].

The development of biomimetic approaches is a promising direction for increasing durability and efficiency in construction, creating new directions for the development of modern ecological architecture aimed at adaptation to the environment.

The study proposes to consider the directions and prospects for the development of biomimetic approaches in creating color solutions for modern ecological architecture.

## **2. Formation of biomimetic color formation approach**

The development of various effective approaches to the design of ecological architecture requires a developed complex apparatus of various scientific knowledge, as well as the formation of a base of analogues of the natural world, biological systems, including the inclusion of the coloristic component of education.

### *2.1. Color application in architecture*

From the point of view of the means of an architect and designer in creating a subject space, color is one of the main tools in the formation of compositional solutions in accordance with the selected color range and the appropriate use of their optical properties. This is achieved due to the texture and texturelessness of the colored surface (texture of the material, contrast, visual memory, special observation conditions) [5]. Revealing or masking the texture and texture of a material using color is closely related to tectonics – the artistic expression of essential physical and decorative properties through the plasticity of the form [6]. The correspondence between material and form is an important condition for overall tectonicity, aesthetics and harmony. According to research, an important role is played by the material, its physical and technical capabilities, as well as the joint work of material and structure [7]. The formation of the visual perception of buildings in coloristic design is influenced by: a) natural and climatic features; b) coloration of the urban environment; c) associative and psychological impact of color d) color-compositional solutions, taking into account tectonics, shape, scale, texture; e) traditional perception of color, taking into account the socio-cultural characteristics of the area.

### *2.2. Color formation in nature*

The analysis of the research made it possible to determine that the harmony of coloristic solutions in nature is associated with the provision of tasks of functional expediency, optimization of adaptation to the environment and living conditions due to the protective or camouflage function; communication signal; thermoregulation; optimization of the spectrum of rays absorbed by leaves during photosynthesis [1, 8, 9].

In living and inanimate nature, color change is a reaction to changing environmental conditions. Coloring in nature is characterized by various kinds of variability: a) irreversibility with time or age, for example, how leaves change color according to seasons, which is associated with the synthesis, accumulation and decay of pigments [8]; b) reverse phenomena, when a color change occurs as a reaction to changing environmental factors and is provided by the movement of pigment granules or special pigment cells (melanophores). This color reaction is associated with the regulation of temperature and humidity: for example, the body of a lizard becomes darker with a decrease in temperature, so that dark colors absorb more heat, and conversely, with an increase in temperature, a lizard can become very pale because light colors reflect heat; Hercules beetle (*Dynastes hercules*) has a greenish-red color at normal humidity, however, if the air humidity exceeds 80%, the color changes to

black due to the filling of air cavities with moisture in the structure of the chitinous cover of the elytra [8].

The process of evolution and adaptation of color in nature optimizes the mechanism of its formation. As a result of the analysis of research, the following mechanisms of color formation in nature should be distinguished:

1. Pigment (chemical), which is associated with the ability of certain molecules (pigments) to selectively absorb, reflect or emit light with a certain wavelength. Pigmentation in living nature occurs by its own synthesis or through the process of nutrition [8].

2. Structural (other names – iridescence or irisation), where the formation of color is based on physical processes and depends on the microstructure of surfaces, on which light from the source falls, causes diffraction or interference of light [9]. In all cases, irisation is based on nanostructures in the form of ribs, fibers, plates, organized in regularly spaced rows or lattices (in physics, structures of this type are called photonic crystals). Photonic crystals create specific optical effects such as diffraction and interference. For the interference effect to occur, it is necessary that the light waves repeatedly reflected from the array elements are in the same phase. The amplitudes of the waves for which this condition is met are added, and the wavelengths of these waves determine the color background [9].

3. Combined – a combination of structural and pigment mechanisms, enhances their action and forms a variegated palette [9].

Thus, the variety of colors in nature is created due to evolution, is built according to the laws of optical physics and a complex system of the structure of living cells and tissues, has its own content and function. The process of evolution and adaptation of color in nature optimizes the mechanism of its formation.

### 3. Examples of the formation of a biomimetic approach to the use of color in solving problems of ecological architecture

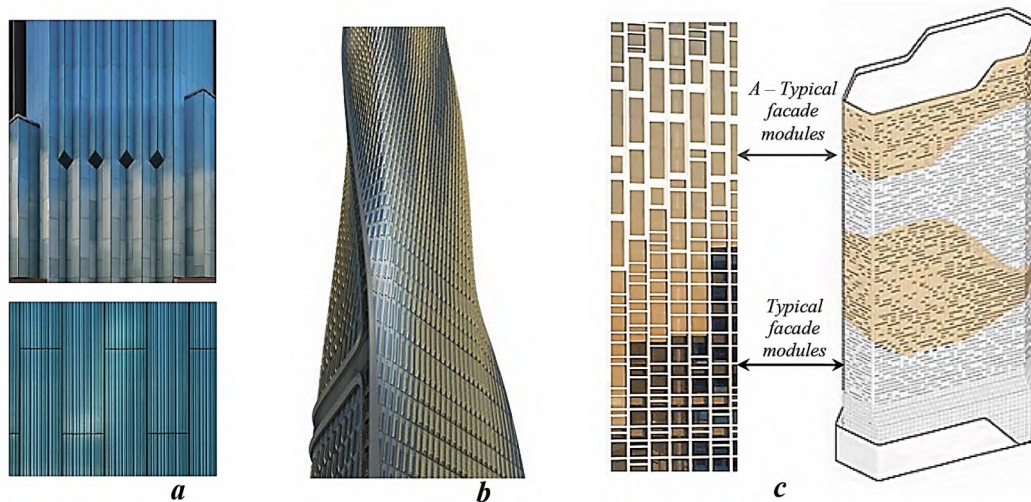
The use of natural analogues of color formation in ecological architecture makes it possible to apply new, more energy-saving, natural, ecological and durable mechanisms for obtaining color solutions for home design. For example, each color has certain strength of absorption and reflection of light, depending on its spectral composition and light sources. If the color belongs to a certain texture of the material, then the effect of its reflection, or the strength of brightness will change, and accordingly the perception of the form, the carrier of the given color, will also change. Understanding the functional basis of the formation of colors in nature makes it possible to consciously use color as a means of regulating energy efficient and environmental parameters in ecological architecture (table 1).

**Table 1.** Application of natural analogues of color formation in ecological architecture.

№	Functions	Natural solutions	Application in ecological architecture
1	Thermoregulation	Natural mechanisms for the formation of visible color and gloss, affecting the degree of heat absorption	Thermoregulation through the color of the façade (light to dark, matt to glossy) will provide varying degrees of heat absorption
2	Humidity control	Natural mechanism of color return when external climatic parameters change	The use of a "smart facade" in the system, which can react to the degree of moisture or heat absorption by changing color (for example, nanofilm – moisture indicator, changes color [10])
3	Ensuring durability	Structural mechanism of color formation	Application of the natural mechanism of the structural formation of color in the decoration of facades

4	Light control	Natural mechanisms for the formation of visible color and gloss that affect the light reflection degree	Regulation of illumination of facades of buildings, streets, premises when using different colors, is provided by different degrees of light reflection for different colors
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In connection with the development of the environmental direction in the design of buildings, today there are color solutions aimed at ensuring environmental compatibility with the environment. They are episodic and non-systematic, but reflect the trends in the development of a new ecological approach in the formation of color design of buildings, for example (fig. 1 (a-c)).



**Figure 1 (a-c).** Examples of using biomimetic approaches in shaping color in ecological architecture [11-13].

Key to Figure 1 (a-c):

(a) – Metropolitan Workshop's tower, a 27-storey building in London covered with turquoise glazed structured terracotta tiles, like a chameleon constantly changing color under different lighting conditions, reflecting the color of the river and plants around the house, and also has a natural self-cleaning function [11];

(b) – Wasl Tower, Dubai, United Arab Emirates, glazed clay facade tiles protect against thermal stress entering the building and the impact on its surroundings, providing an effective solution for thermal control of a high-rise building in a desert climate [12];

(c) – Seoul tower, in the Seoul, South Korea has the color scheme of the building facade determined by the geometry and dimensions of the facade elements, taking into account the influence of the Sun and orientation to the cardinal points to ensure user comfort inside the building and reduce energy consumption [13].

### 3.1. Discuss

In architecture, color is used as an important means of visual impact in an urban environment, in the formation of visual perception of the form, texture, material of a building. A significant number of studies are devoted to these issues [10, 14]. For the development of ecological architecture, it is promising to use analogs of coloristic solutions in nature, based on functional feasibility, optimization of adaptation to the environment, living conditions, are studied in various fields of studying nature [1, 2]. It should be noted that there are no systemic studies on the formation of approaches to the use of various means of color formation in living and inanimate nature to solve problems of ecological design and architecture, namely, to ensure their durability and to regulate energy-efficient and environmental parameters (thermoregulation, illumination regulation, humidity). The approach proposed in the article

for the introduction of means and approaches for the formation of color in nature, as the basis for color education in accordance with functional and applied application, makes it possible to develop and solve the problems of ecological architecture.

#### 4. Summary

Research results make it possible to establish that today the use of biomimetic approaches to the use of color in the design of buildings determines new trends in the creation of ecological solutions for facades based on the use of natural analogues. An analysis of the use of modern design innovative color solutions in buildings shows the relevance of the dissemination and development of new biomimetic ideas and their implementation in design and design practice in order to create an aesthetic, ecological and energy-efficient urban environment in accordance with environmental conditions. The addition of biomimetics, which defines approaches to nature as a source of knowledge and requirements for building design, provides the development of ecological architecture and a direction for further research.

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