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Molecular & Cellular Biomechanics 2025, 22(5), 1437.
https://doi.org/10.62617/mcb1437

Article

Application of biological morphology research in microscience to visual arts

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CITATION

Zhang C, Ma C, Zhang S. Application of biological morphology research in microscience to visual arts. Molecular & Cellular Biomechanics. 2025; 22(5): 1437. https://doi.org/10.62617/mcb1437

ARTICLE INFO

Received: 23 January 2025
Accepted: 19 February 2025
Available online: 24 March 2025

Abstract: Research on biological morphologies in microscience offers a rich source of inspiration for visual arts. By analyzing the mechanical properties of cells, molecules, and tissues, a deep integration of science and art can be achieved. Based on the cobweb lattice structure and combining the mechanical response of biological tissues in dynamic environments, a biomimetic design model is constructed. The experimental methodology centers on microscopic observation techniques, utilizing microscopes to collect three-dimensional morphological data of cells and tissues, and employing finite element analysis to simulate their stress behavior. On this foundation, morphological models with both biomechanical accuracy and artistic expressiveness are designed, and innovative applications in installation art are realized through technological means such as 3D printing. Research results indicate that the elastic modulus of cells plays a decisive role in morphological stability, with the optimized biomimetic morphological structure exhibiting a reduction of over 30% in deformation amplitude in dynamic environments. Analysis of intermolecular mechanical interactions provides a refined design basis for artistic creation. Research on biological morphologies in microscience not only enriches the expressive forms of visual arts but also opens up new technological pathways and creative spaces for biomimetic design.

Keywords: microscience; biological morphology; visual arts; biomimetic design; experimental analysis

1. Introduction

The development of microscience has paved new avenues for the study of biological morphologies. By analyzing the microstructures and mechanical properties of cells, molecules, and biological tissues, scholars from various disciplines have gained deeper insights into the multifunctionality of biological structures in nature [1–3]. This exploration into the microscopic realm has not only enhanced our understanding of biological systems but has also opened up possibilities for new applications across various fields, including medicine, materials science, and environmental studies. The intricate details uncovered through advanced microscopy techniques reveal how nature has optimized structures for specific functions, inspiring innovations that mimic these designs in human-made systems. Meanwhile, visual arts, as a vital form of human emotional expression and cultural dissemination, have increasingly relied on science and technology in recent years. The intersection of art and science has led to a new era in artistic expression, where artists are not only creators but also researchers who delve into the scientific principles underlying their work. This synergy has fostered the emergence of new media arts, which utilize digital technologies to create immersive experiences that engage audiences on multiple levels. As artists incorporate scientific insights into their practices, they are able to push the boundaries of traditional art forms, creating pieces that resonate with contemporary societal themes and technological advancements. In particular, new media arts and dynamic art installations have placed higher demands on the integration of scientific and artistic elements. These installations often require a deep understanding of both aesthetic principles and the scientific concepts that inform their design. For instance, kinetic sculptures that respond to environmental stimuli or interactive installations that involve viewer participation necessitate a sophisticated grasp of mechanics and material properties. As artists experiment with these new forms, they must navigate the complexities of creating works that are not only visually striking but also functionally sound, leading to a rich dialogue between artistic intent and scientific rigor. Biological morphologies, as highly optimized geometric and mechanical manifestations in nature, not only exhibit remarkable functional adaptability but also possess rich aesthetic value in artistic design [4–6]. The study of these morphologies reveals patterns and structures that can be translated into artistic practice, offering a wealth of inspiration for artists seeking to create works that reflect the beauty of the natural world. By understanding the principles of biomimicry, artists can develop designs that are both innovative and grounded in the realities of biological efficiency, thereby enhancing the viewer's appreciation of the interplay between form and function. Current research primarily focuses on the application of biomimetic structures in engineering and materials science, such as lightweight energy-absorbing structures and efficient energy transfer devices. These advancements highlight the potential for nature-inspired designs to revolutionize various industries, demonstrating how biological principles can lead to more sustainable and effective solutions. However, the challenge remains to translate these findings into the realm of visual arts, where the focus often shifts from functionality to expression. This gap presents a unique opportunity for interdisciplinary collaboration, where insights from engineering can inform artistic practice and vice versa. However, in the field of visual arts, numerous challenges remain in deeply integrating scientific research on biological morphologies with artistic expression [7–9]. One significant hurdle is the tendency for biomimetic designs to prioritize engineering applications over artistic considerations. As a result, many designs may lack the emotional resonance or aesthetic qualities that are essential in art. To address this issue, artists and scientists must work together to create designs that are not only functional but also evoke a sense of wonder and connection to the natural world. On the one hand, existing biomimetic structural designs are mostly oriented towards engineering needs, lacking consideration for artistic expressiveness. This focus can lead to a disconnect between the scientific principles that inform the designs and the artistic narratives that they could convey. Artists must actively engage with the underlying science to ensure that their work encapsulates both the technical and emotional dimensions of their subject matter. On the other hand, the requirements for structural mechanics in the field of visual arts are gradually increasing, and finding a balance between complex mechanical properties and formal beauty poses a research difficulty [10–12]. As artists experiment with new materials and technologies, they are challenged to create works that can withstand the rigors of installation while maintaining their aesthetic integrity. This balancing act requires a deep understanding of both artistic vision and the scientific principles that govern material behavior, necessitating ongoing dialogue between artists and engineers. Furthermore, there is a mismatch between the multiscale characteristics of biological morphologies and traditional artistic design methods, necessitating higher demands for innovation in design tools and theories [13,14]. At a time when the demand for innovative art forms and sustainable design is increasing globally, artists and designers are being challenged to combine traditional art with emerging technologies. Microscience, especially the study of biological morphology, provides a new source of inspiration for artistic creation. The complex structure and function of these microscopic forms are not only the exquisite expression of nature, but also bring a breakthrough perspective for the creation of visual art. For example, the morphological characteristics of cells, molecules, and biological tissues can inspire artists to incorporate more vivid, dynamic, and functional elements into their creations. With the progress of science and technology, the media and methods of artistic creation are constantly innovated, and the interdisciplinary integration of biological morphology research can promote the further development of visual art and provide new forms and concepts for artistic expression. Therefore, the study of biological morphology plays an increasingly important role in driving innovation and breakthroughs in visual art, especially in the fields of sustainable design and dynamic art installations.

To bridge this gap, new design methodologies must be developed that can accommodate the complexity of biological forms. This may involve the use of computational design tools that allow for the exploration of intricate geometries and the simulation of mechanical properties, enabling artists to visualize and manipulate their ideas in ways that were previously unimaginable. In response to these issues, this research explores biomimetic design methods that combine microscopic biological morphological characteristics with visual artistic expression, fully leveraging the potential of microscience in structural function and geometric aesthetics to provide new technical means and design ideas for artistic creation. By synthesizing insights from both biology and art, this research aims to foster a new paradigm of design that is rooted in the principles of nature. This approach not only enhances the creative process but also encourages a deeper appreciation of the interconnectedness of all disciplines. This interdisciplinary fusion research will provide important academic reference and practical value for the innovative development of visual arts. Ultimately, the goal is to create a new language of design that speaks to the beauty and complexity of the natural world, enriching both artistic practice and scientific inquiry. By embracing the potential of biomimicry and microscience, artists can create works that resonate on multiple levels, engaging audiences in a dialogue that transcends traditional boundaries and inspires future generations.

2. Mechanical properties of biological morphologies and biomimetic model construction

2.1. Cellular mechanical analysis and its artistic inspiration

Cells, as fundamental biomechanical units, possess elastic and viscous properties that are crucial for understanding the behaviors of complex biological morphologies.

The mechanical attributes of cells not only determine their deformation patterns under stress but also offer significant inspiration for the construction of biomimetic morphologies in visual arts [13–15]. The mechanical behavior of cells typically exhibits nonlinear elasticity, with their stress-strain relationship represented by an advanced form of a nonlinear model.

$$\sigma = E_1\varepsilon + E_2\varepsilon^2 + E_3\varepsilon^3 \tag{1}$$

In this context, σ represents the stress, ε denotes the strain, and E_i stands for the higher-order coefficient of the elastic modulus, which respectively describe the linear, second-order, and third-order elastic effects to accurately characterize the mechanical behavior of cells within high strain ranges. In practical analysis, the deformation of cells is also constrained by the surrounding medium. By introducing a correction factor k_s, a stress formula that incorporates external constraints is obtained.

$$\sigma_{eff} = (E_1 + k_s)\varepsilon + E_2\varepsilon^2 \tag{2}$$

Herein, k_s represents the constraint coefficient of the environmental medium on cellular deformation. This formula not only reflects the internal elastic properties of cells but also incorporates the modulation effect of the external environment on their mechanical behavior, providing a precise description for biomimetic morphology design. For the analysis of cellular viscous properties, the viscous behavior of cells can be described using a generalized viscoelastic model, which is based on the modified Kelvin-Voigt model and incorporates a dissipation factor η_d to represent energy loss.

$$\eta_{eff} = \eta_0 + \eta_d e^{-\alpha t} \tag{3}$$

In this equation, η_{eff} denotes the effective viscosity coefficient, η_0 represents the initial viscosity, α is the attenuation factor, and t stands for time. By combining elastic and viscous properties, the mechanical behavior of cells in a dynamic environment can be expressed through the motion equation in Equation (4).

$$m\frac{d^2u}{dt^2} + c\frac{du}{dt} + ku = F(t) \tag{4}$$

In this equation, m represents the mass of the cell, $c = \eta_{eff}$ denotes the viscosity coefficient, $k = E_{eff}$ stands for the equivalent elastic coefficient, u is the displacement, and $F(t)$ represents the external force. By optimizing and adjusting the parameters c and k, a cellular mechanical model that meets artistic requirements can be designed.

2.2. Modeling intermolecular mechanical interactions

Intermolecular mechanical interactions serve as the microscopic foundation for the stability of biological morphologies and the realization of their functions. Modeling these interactions allows for the analysis of behavioral patterns in complex biological structures and enables biomimetic design [16–18]. Research efforts have focused on refining traditional molecular mechanics models to more accurately depict mechanical effects at the molecular level. The total force of intermolecular interactions can be expressed in Equation (5) by combining van der Waals forces, electric double-layer forces, and elastic forces between molecular chains.

$$F_{total} = \frac{A}{r^6} - \frac{B}{r^2} + C\,ln(r) + k_0(r - r_0) \tag{5}$$

In this context, r denotes the intermolecular distance, A and B are the attraction and repulsion coefficients for van der Waals forces, respectively, C is the adjustment coefficient for electric double-layer interactions, k_0 represents the elastic recovery coefficient, and r_0 (note: here I've used R_0 to avoid confusion with the intermolecular distance R) is the equilibrium distance between molecules. Compared with traditional models, this study introduces nonlinear elastic effects between molecular chains to more closely approximate actual behavior in complex biological environments. To describe the mechanical stability between molecules, a potential energy function $U(r)$ can be introduced, whose expression is as follows.

$$U(r) = -\frac{A}{12r^6} + \frac{B}{4r^2} - C\,ln(r) + \frac{k_0}{2}(r - r_0)^2 \tag{6}$$

This formula is derived from mechanical integration and represents the potential energy distribution between molecules at different distances. The equilibrium position can be obtained by differentiating $U(r)$, as shown in Equation (7).

$$r_{eq} = \left(\frac{6A}{B + 2k_0 r_0}\right)^{\frac{1}{6}} \tag{7}$$

The existence of the equilibrium distance r_{eq} ensures structural stability between molecules and provides a theoretical basis for optimizing intermolecular structures in biomimetic design. In a dynamic environment, intermolecular interactions are influenced by viscous damping, and their dynamic behavior can be described by the intermolecular force balance equation, as shown in Equation (8).

$$m\frac{d^2r}{dt^2} + \eta\frac{dr}{dt} + \frac{\partial U}{\partial r} = F_{ext} \tag{8}$$

In this equation, m represents the molecular mass, η denotes the damping coefficient, and F_{ext} stands for the external force. The aforementioned equation indicates that intermolecular interaction forces are modulated by viscosity and external forces under dynamic conditions. By optimizing η and F_{ext}, the mechanical response of biomimetic materials in different environments can be simulated. Meanwhile, to implement the application of the mechanical model, it is necessary to optimize the parameters based on experimental data. Combining finite element simulations, a target function G is defined as the sum of squared deviations between the intermolecular forces and experimental observations.

$$G = \sum_{i=1}^{n\Sigma} (F_{sim}(r_i) - Fi^2{}_{exp} \tag{9}$$

By iteratively optimizing parameters such as A, B, C, k_0, and others, the fitting accuracy of the model is improved, providing reliable support for practical biomimetic design.

2.3. Biomorphic biomimetic design and its performance optimization in visual arts

biomimetic design integrates the biological forms of microscience with artistic expression, creating visual art forms that possess both functional and aesthetic value through the abstraction and optimization of the structural characteristics of natural organisms [19–21]. In visual art creation, the biomimetic design of dot matrix structures, especially optimized models based on the geometric patterns of spider webs, can provide multi-dimensional inspiration for dynamic installations and art sculptures. As shown in **Figure 1**.

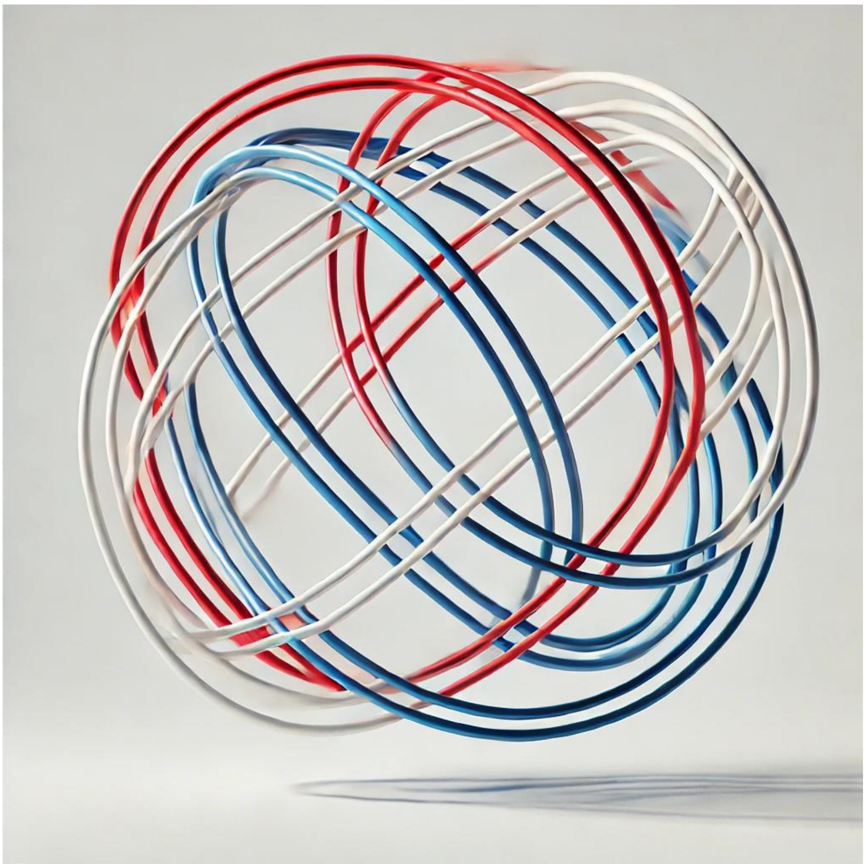

Figure 1. Biomimetic dot matrix art design based on spider web geometry.

The following discussion covers three aspects: parametric modeling of dot matrix structures, performance analysis, and artistic applications. In the design of dot matrix structures for biomimetic art, the combination of radial and spiral lines embodies the exquisite structures found in nature. Through reasonable geometric modeling and parameter optimization, the expressive power and energy absorption performance of the structures are enhanced. The optimization formula for the length of the radial lines is as follows.

$$L_1 = \int_a^b \sqrt{[f'(x)]^2 + 1}dx \tag{10}$$

In this formula, L represents the length of the radial line, and $f(x)$ is the shape function of the radial line. This formula is used to precisely define the shape and ductility of curves in visual arts, providing diverse visual dynamic effects for artistic expression.

In artistic modeling design, the geometric characteristics of spiral structures are described by the following formula.

$$\theta = \frac{\pi r}{h} \tag{11}$$

In the formula, r represents the base diameter of the spiral, and h is the pitch. By adjusting the ratio of the spiral angle to the base diameter, highly dynamic installation art pieces can be created, achieving a visual transition from static to dynamic [22,23]. To achieve multifunctionality in artistic installations, the volume and porosity of the dot matrix structure need to be optimized to balance mechanical performance and visual permeability. The volume of the dot matrix structural unit can be calculated using the following formula.

$$V_t = S_{L,N} + S_{L_2,N_2} \tag{12}$$

In this formula, $S_{L,N}$ and S_{L_2,N_2} represent the cross-sectional area and quantity of radial lines and spiral lines, respectively. By adjusting the volume parameters of the dot matrix structure, a unified presentation of lightweight and aesthetics can be achieved in visual artworks. In performance analysis, the relative elastic modulus of the biomimetic structure determines its manifestation in different environments and can be calculated using the following formula.

$$E_r = \frac{S_t}{S_s} E_s \tag{13}$$

In the formula, S_t and S_s represent the actual bearing area and the theoretical bearing area, respectively, while E_s is the elastic modulus of the material matrix. By optimizing the bearing area, the stability and durability of artistic installations can be enhanced [24–26].

In dynamic art installations, the formula for energy absorption performance is as follows.

$$E_a = \int_0^d f(s) ds \tag{14}$$

In this formula, d represents the deformation displacement, and $f(s)$ stands for the stress-strain curve. Through this formula, energy dissipation and structural response of dynamic installations under external force can be analyzed, providing scientific support for artistic creation.

To sum up, although biomimetic design provides innovative theoretical basis and structural optimization scheme for visual art creation, in practical application, how to translate these designs into artistic works is still a key issue. In order to make up for this gap, this study discusses the practical application of biomimetic design in dynamic art installations. By optimizing and adjusting the geometric parameters of biomimetic lattice structures, the design not only has good mechanical properties, but also realizes the richness and uniqueness of artistic expression. By drawing on the geometry of spider webs, highly expressive and interactive dynamic installations are designed that respond to changes in the external environment and interact with the audience. Specific experiments are described below.

3. Experimental and application analysis

3.1. Experimental environment configuration

The experimental environment for this study encompasses hardware configuration, software support, and the setup of practical operating scenarios. The aim is to provide scientific support for modeling, performance testing, and visual art creation of biomimetic structures.

The hardware used in the experiment primarily includes the following equipment: high-resolution Scanning Electron Microscope (SEM), three-dimensional modeling workstation, multi-functional 3D printer, and quasi-static compression testing machine. The following software was utilized for data acquisition, modeling, and analysis: ANSYS Workbench, MATLAB, and Rhinoceros + Grasshopper.

3.2. Experimental and application analysis

3.2.1. Mechanical performance analysis and artistic application exploration of biomimetic dot matrix structures

To verify the mechanical properties of biomimetic dot matrix structures and their applicability in artistic creation, systematic compression performance tests were conducted on ordinary spider's web structures, spiral biomimetic structures, and composite biomimetic structures. Quasi-static compression experiments were used to record the compression force and energy absorption at different displacement conditions, enabling quantitative analysis of the performance characteristics of these structures and providing a scientific basis for their application in artistic design. The experimental results are presented in **Table 1**.

Table 1. Mechanical performance data of biomimetic lattice structures under compression conditions.

Compression Displacement (mm)	Compressive Force (N)—Simple Structure	Compressive Force (N)—Spiral Structure	Compressive Force (N)—Composite Structure	Absorbed Energy (J)—Simple Structure	Absorbed Energy (J)—Spiral Structure	Absorbed Energy (J)—Composite Structure
1	50	70	95	0.12	0.16	0.2
2	140	210	260	0.34	0.5	0.62
3	200	310	360	0.63	0.89	1.1
4	260	400	460	1.05	1.36	1.65
5	320	470	530	1.54	1.94	2.21
6	370	520	600	2.15	2.58	2.89
7	440	610	680	2.9	3.4	3.68
8	490	710	770	3.61	4.2	4.62
9	550	810	870	4.4	5.06	5.54
10	620	920	990	5.33	5.98	6.48

From **Table 1**, it can be observed in terms of compression performance characteristics that the ordinary spider's web structure exhibits lower compression forces at all displacement stages compared to the other two structures (e.g., 50 N at 1 mm displacement and 620 N at 10 mm displacement), indicating moderate but relatively uniform mechanical properties suitable for expressing static artistic forms. The spiral biomimetic structure demonstrates a stronger mechanical response, particularly when the displacement exceeds 6 mm (above 520 N), making it suitable for the design of dynamic artistic expressions. The composite biomimetic structure exhibits optimal mechanical properties at all displacement stages, with a compression force of 990 N at 10 mm displacement, representing an approximately 59.7% increase compared to the ordinary structure, thereby providing higher bearing capacity and design space for complex dynamic art installations. In terms of energy absorption performance and artistic expression, the data reveals that the composite biomimetic structure also has an advantage in energy absorption. At a displacement of 10 mm, its energy absorption reaches 6.48 J, which is 21.6% and 8.4% higher than that of the ordinary and spiral structures, respectively. This characteristic makes the composite biomimetic structure more suitable for artistic creation involving high-energy interactive installations, such as those requiring withstanding multiple interactions or dynamic changes. The ordinary structure exhibits stable energy absorption performance, suitable for expressing quiet visual artistic forms, while the spiral structure demonstrates high elastic energy absorption capacity, suitable for works with stronger dynamic interactivity. For artistic design inspired by microscopic biological forms, biomimetic designs based on microscopic scientific biological forms can infuse visual artworks with new mechanical and geometric aesthetics. By incorporating the mechanical advantages of nature, spiral and composite dot matrix structures not only enhance structural performance but also exhibit dynamic artistic expressions in form. In summary, the differences in compression performance and energy absorption capabilities of biomimetic dot matrix structures provide abundant creative space for visual art design. The composite biomimetic structure stands out particularly in dynamic and interactive art, while the elastic properties of the spiral structure are suitable for device designs emphasizing a sense of fluidity.

3.2.2. Optimization and energy absorption performance analysis of spiral biomimetic dot matrix structures

In the context of the integration of microscopic science and visual arts, the impact of key geometric parameters (spiral turns and pitch) of spiral biomimetic dot matrix structures on energy absorption performance is investigated. Through finite element simulations and experimental tests, the optimization effects of different parameter combinations on total energy absorption are analyzed, and a three-dimensional performance response map is generated, as shown in **Figure 2**.

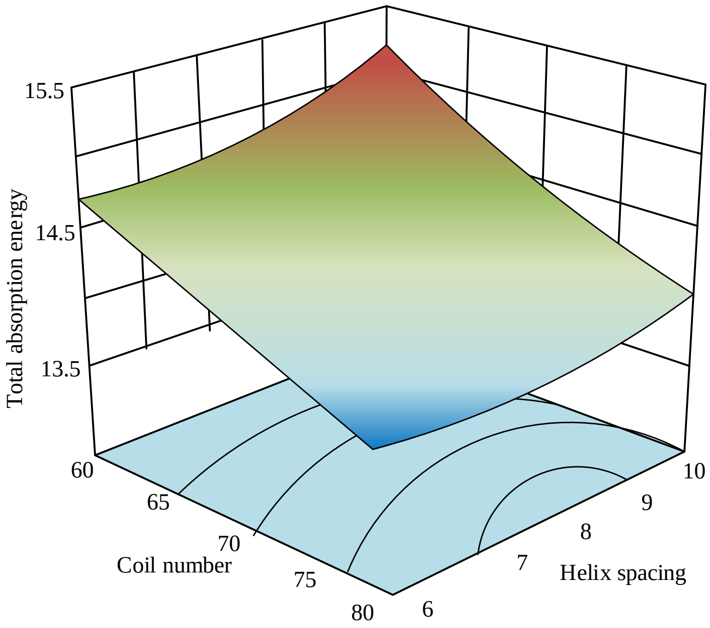

Figure 2. Optimization and energy absorption performance of spiral biomimetic dot matrix structures.

As shown in **Figure 2**, there is a notable trend of increasing total energy absorption with the augmentation of spiral turns. When the number of spiral turns increases from 60 to 80, the total energy absorption rises from approximately 13.5 J to 15.5 J. This indicates that a greater number of spiral turns can effectively distribute external forces and enhance the energy absorption capacity of the dot matrix structure, further enhancing its expressive power and functionality in artistic design. The impact of pitch on energy absorption performance exhibits a nonlinear relationship. As the pitch gradually increases from 6 to 9, the total energy absorption first increases and then decreases. Within the range of 7 to 8, the total energy absorption reaches its maximum, suggesting that an appropriate pitch can optimize mechanical properties within limited space while providing more inspiration for artistic creation. An excessively large pitch may reduce structural stability, thereby weakening the energy absorption capacity. Meanwhile, the three-dimensional response depicted in the figure reveals a synergistic effect of the combination of spiral turns and pitch on energy absorption performance. The total energy absorption peaks when there are a high number of spiral turns and a medium pitch (approximately 7.5). The selection of these optimized parameters can provide a design basis for dynamic art installations, such as interactive works or sculptures that need to withstand high impact forces. Therefore, from the perspective of applications in visual arts, the optimization of spiral biomimetic dot matrix structures not only enhances energy absorption performance but also provides a robust geometric foundation for visual artistic creation. In dynamic art applications, the optimized spiral structure can achieve unity of form and function through parameter adjustments. For instance, structures with a higher number of spiral turns can create complex spatial hierarchy, while a medium pitch can enhance the visual tension and sense of fluidity of the artwork. This innovative design combining science and art will further promote the application of microscopic biological forms in the field of art.

In order to enhance the practical significance of this study, dynamic impact and fatigue test data are studied and analyzed to comprehensively evaluate the performance of bionic structures in actual art installations, especially the stability and durability under high dynamic environments. The results are shown in **Table 2**.

Table 2. Test data of dynamic shock and vibration frequency response.

Vibration frequency (Hz)	Displacement (mm)	Stress (N)	Energy Absorption (J)	Vibration period (s)	Peak response (N)
1	0.12	25	0.03	1	30
2	0.15	38	0.06	0.5	45
3	0.18	48	0.09	0.33	55
4	0.22	60	0.14	0.25	70
5	0.26	72	0.18	0.2	85
6	0.3	85	0.23	0.17	95
7	0.35	95	0.29	0.14	105
8	0.4	110	0.35	0.13	120
9	0.45	120	0.4	0.11	130
10	0.5	135	0.45	0.1	150

The vibration frequency response test data show that with the increase of vibration frequency, the displacement, stress and energy absorption of the bionic structure show a gradual increase trend. For example, from 1 Hz to 10 Hz, the displacement increases from 0.12 mm to 0.50 mm, indicating that the deformation amplitude of the bionic structure increases at high frequencies. The stress value also showed an increasing trend with the increase of frequency, with the lowest value being 25 N (1 Hz) and the highest value being 135 N (10 Hz), reflecting the increased stress of the structure under high-frequency vibration. At the same time, the energy absorption also increases with the increase of frequency, from 0.03 J (1 Hz) to 0.45 J (10 Hz), indicating that at a higher frequency, the bionic structure can effectively absorb more external impact energy, helping to improve its performance in a dynamic environment. In addition, the vibration period is shortened with the increase of frequency, which indicates that the response time of the structure at high frequency is shortened, thus improving the dynamic response speed of the system. The change of peak response is consistent with the trend of stress, reaching up to 150 N (10 Hz), indicating that the instantaneous response experienced by the structure under high frequency vibration increases, which needs to be considered in the design to ensure the stability and durability of the structure in practical applications.

3.2.3. Psychological and aesthetic research

In order to analyze and reveal the audience's perception and preference of different biomimetic geometric forms, psychological experiments and aesthetic analysis were carried out to verify the applicability of biomimetic structures in visual art through quantitative investigation and data analysis. A total of 1000 participants (1:1 male/female, age range 18–50 years) from different cultural backgrounds (including but not limited to East Asia, Europe, America, South America, and Africa) were recruited and asked to perceive and evaluate images of art installations with different biomimetic structures. The test included indicators of visual perception, including visual complexity, geometric symmetry, and dynamic perception. Indicators of emotional response: comfort, attraction and sense of innovation. Overall aesthetic rating: Considering the above factors, the rating range is 1–10 points. Through the combination of online questionnaire and on-site display, the pictures and 3D models of ordinary biomimetic structure, spiral biomimetic structure and composite biomimetic structure are displayed respectively, and the feedback of the audience is recorded. The results are shown in **Table 3**.

Table 3. Psychological and aesthetic data of different biomimetic lattice structures.

Index	**Simple Structure**	**Spiral Structure**	**Composite Structure**
Visual Complexity Score	5.2 ± 1.1	7.8 ± 1.4	8.5 ± 1.3
Geometric Symmetry Score	6.8 ± 0.9	6.3 ± 1.2	7.0 ± 1.1
Dynamic Perception Score	4.7 ± 1.0	8.1 ± 1.5	8.7 ± 1.2
Comfort Score	6.2 ± 1.0	7.4 ± 1.2	7.9 ± 1.1
Attraction Score	5.5 ± 1.3	8.0 ± 1.4	8.6 ± 1.2
Innovation Perception Score	5.0 ± 1.2	7.6 ± 1.3	8.8 ± 1.1
Overall Aesthetic Score (1–10)	5.6 ± 1.2	7.9 ± 1.4	8.7 ± 1.2

As can be seen from **Table 3**, the composite structure scores the highest in terms of visual complexity (8.5) and sense of motion (8.7), demonstrating stronger artistic expression. The spiral structure follows closely behind, while the common structure, due to its simple design, scores the lowest on these two indicators (5.2 and 4.7, respectively). Although the composite structure performs well in terms of geometric symmetry and comfort (scoring 7.0 and 7.9, respectively), the common structure ranks second only to the composite structure in geometric symmetry, indicating that simple geometry has certain visual stability advantages among audiences. The composite structure significantly outperforms the other two structures in terms of attractiveness (8.6) and sense of innovation (8.8), suggesting that complex biomimetic designs can not only spark audience interest but also exhibit high innovative value. The design of biomimetic dot matrix structures can enhance visual complexity and sense of motion to meet the needs of dynamic art installations and interactive works. Incorporating psychological indicators into artistic creation and optimizing design through symmetry and comfort can make artworks both attractive and provide a comfortable viewing experience. By enhancing the sense of innovation in design, biomimetic structures can occupy an important position in new media art and modern sculpture, bringing unique visual and psychological experiences to audiences.

4. Conclusion

The study of biological morphologies in microscience has provided a novel source of inspiration for visual arts. By analyzing the mechanical properties of cells, molecules, and tissues, it is possible to combine scientific accuracy with artistic expression, thereby promoting the application of biomimetic design in visual arts. This research aims to explore the innovative application of biomimetic designs based on spider's web dot matrix structures in dynamic art installations. The results indicate that spiral and composite biomimetic dot matrix structures exhibit significant mechanical property optimizations. Under a compression displacement of 10 mm, the composite structure achieves a compressive force of 990 N, which is approximately 59.7% higher than that of the common structure, with an energy absorption increase of 21.6%. This performance makes it suitable for dynamic art installations requiring high load-bearing capacity and energy absorption. Through the study of spiral turns and pitch, it was found that a combination of high spiral turns (80) and medium pitch (7.5) results in a peak total energy absorption of 15.5 J. The optimized structural design provides an effective geometric foundation for dynamic artistic creation. Psychological experiment results show that composite biomimetic structures perform best in terms of attractiveness, sense of innovation, and overall aesthetic ratings (with an overall score of 8.7), followed by spiral structures. This suggests that complex biomimetic designs better meet audiences' aesthetic expectations and emotional appeals for artworks. Despite significant research achievements, there are still some limitations. This study was mainly conducted under quasi-static loading conditions, and the long-term performance of biomimetic structures under dynamic impact or cyclic loading was not fully investigated. Additionally, the sample size for psychological and aesthetic experiments was relatively small, and the diversity of cultural backgrounds and aesthetic preferences was not fully represented. Therefore, broader surveys are needed in the future. At the same time, future research should expand the experimental scope to explore the influence of different environmental conditions and diversified structural forms on the biomimetic design effect. In addition, the research outlook should focus on solving how to optimize biomimetic design to adapt to more complex artistic creation needs, especially in dynamic art installations and interactive art works. In view of these problems, interdisciplinary experimental research can be further carried out in the future, and detailed research plans can be formulated to promote the application of biomimetic design in visual art.

Author contributions: Conceptualization, CZ and CM; methodology, CZ; software, CZ; validation, CZ, CM and SZ; formal analysis, CZ; investigation, CZ; resources, CZ; data curation, CZ; writing—original draft preparation, CZ; writing—review and editing, CM; visualization, SZ; supervision, CM; project administration, CZ; funding acquisition, CM. All authors have read and agreed to the published version of the manuscript.

Ethical approval: Not applicable.

Conflict of interest: The authors declare no conflict of interest.

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