Nanotechnology Perceptions
ISSN 1660-6795
www.nano-ntp.com

Nanorobotics Inspired By Biomimicry Review

Daniel Jose Martinez Romero[1] , Luz Helena Camargo Casallas[2]

[1] *[Universidad Distrital Francisco José de Caldas, Colombia]*
Email: djmartinezr@udistrital.edu.co
ORCID: https://orcid.org/0009-0005-8198-4551
[2] *[Universidad Distrital Francisco José de Caldas, Colombia]*
Email: lhcamargoc@udistrital.edu.co
ORCID: https://orcid.org/0000-0002-3416-018X

Objective: This review analyzes the current state of the art in biomimicry-inspired nanorobotics, focusing on how biological principles are translated into the design, locomotion, control, and functionalization of micro- and nanoscale robotic systems, with particular emphasis on engineering and biomedical applications.

Methodology: A structured literature review was conducted using a bibliometric approach based on the PubMed database. The search strategy included the keywords nanorobotics and biomimicry, applied to titles, abstracts, and keywords. Only terms with a minimum frequency threshold were considered to strengthen thematic relevance and identify dominant research trends. Complementary qualitative analysis was performed to synthesize technological strategies, biological inspirations, and application domains.

Results: The analysis reveals that biomimetic locomotion strategies—especially those inspired by flagellated microorganisms and implemented through helical geometries with magnetic actuation—constitute the most mature and widely adopted approaches in nanorobotics. In parallel, the integration of cell membrane camouflage and biomimetic biointerfaces has emerged as a key trend, enhancing biocompatibility, immune evasion, and functional specificity. Engineering applications are predominantly oriented toward targeted drug delivery, minimally invasive procedures, mobile sensing, and cooperative swarm-based systems, while emerging actuation methods such as acoustic and biohybrid approaches expand the functional landscape.

Conclusions: Biomimicry-inspired nanorobotics is consolidating as an interdisciplinary field where biological principles provide robust solutions to fundamental challenges at low Reynolds numbers and complex biological environments. Despite significant advances, challenges related to scalability, multifunctional integration, and clinical translation remain. Future developments are expected to focus on autonomous, cooperative, and multifunctional systems that deepen the integration between biological inspiration and engineering design.

Keywords: Nanorobotics; Biomimicry; Bioinspired locomotion; Magnetic actuation; Cell membrane camouflage; Biomedical engineering; Micro/nanorobots; Swarm robotics.

INTRODUCTION

Nanotechnology, one of the most relevant emerging areas of research in recent decades, together with robotics, has given rise to a new technological paradigm that makes it possible to take advantage of the unique properties of matter at the nanometric scale. From this convergence arises the concept of nanorobotics, a field with high potential for the development of advanced applications in multiple disciplines.

On the other hand, although humans are in a constant process of design, optimization and technological innovation with the aim of improving the quality of life, it is equally relevant to observe how nature and living organisms have developed, over millions of years, highly efficient solutions to solve complex problems (Choi et al., 2015). This biological perspective broadens the spectrum of possibilities in engineering design, showing that, in certain cases, the imitation of natural systems can lead to highly effective technological solutions. In this context, biomimicry is based on the systematic study of nature in order to understand the principles that govern its mechanisms, extract ideas and inspire concepts applicable mainly to science, engineering and medicine.

The aim of this review is to present biomimicry-inspired nanorobotics as an eminently interdisciplinary field, in which knowledge from various areas converges to propose and develop innovative solutions. These efforts have enabled significant advances in areas such as medicine, particularly in the transport and targeted delivery of drugs in biological systems, as well as in the development of new technologies applicable to engineering (Rajendran et al., 2023; Taha, 2024). While biomimicry has driven advances in

In other sectors, such as functional materials and optical systems, this review focuses specifically on those approaches that incorporate biomimetic principles into the design and operation of nanorobots.

Table 1. Compact synthesis of biomimetic nanorobots: inspiration, mechanism, control and engineering applications.

Inspiration	**Mechanism/Strategy**	**Control**	**Application (Engineering)**
Flagellated bacteria flagellum	Helical propulsion (artificialcial)	Magnetic (rotary field)	Navigation and directed transport in viscous fluids.
Micro/nano bio-inspired Swimming microrobots (designs and application frameworks)		Magnetic (rotated- Magnetic + bioin- Interface Biointerface (compatible with external control)	Platforms for tasks in confined environments (biomedical and engineering).
Platelets	Camouflage/functional adhesion by means of membrane		
Cell membranes	Biomimetic and functional coating Surface Nationalization	Biointerface	Immune evasion, reduced biofouling and recognition Specific foundation (targeting).
Natural swarms	Typical coordination *Swarm* (multi-robot)	Magnetic and others	Robustness, spatial coverage and transport cooperative in distributed tasks.
Integrative Review	Taxonomies and Trends Biomimicry-nanotechnology	N/A	Overview of the state of the art and biomimetic connections applicable to nanorobotics.

LITERATURE REVIEW

NANOROBOTICS AND BIOMIMICRY

From a historical perspective, theoretical physicist Richard Feynman was one of the first pioneers to introduce the idea of manipulating and controlling individual atoms and molecules. In his lecture "There's Plenty of Room at the Bottom", he raised the possibility of working at extremely small scales, laying the conceptual foundations of what would later be consolidated as nanotechnology (Feynman, 1999). Currently, this discipline is defined as a multidisciplinary field that involves the manipulation of materials at scales typically between 1 and 100 nanometers, integrating knowledge from physics, chemistry, biology and engineering (Freire, 2025).

The convergence of nanotechnology with disciplines such as electronics and mechanics has led to the development of nanorobotics, a field oriented towards the design and manufacture of nanorobots, understood as electromechanical devices at the micro and nanometric scale conceived to perform specific tasks that are significantly favored by their small size (Rajendran et al., 2023). Due to these characteristics, the most relevant applications of nanorobots have historically been concentrated in the biomedical field, particularly in the diagnosis and treatment of cancer, where they can move through complex biological environments with high levels of precision (Taha, 2024).

Biomimicry, on the other hand, is an interdisciplinary field that seeks the development of technological solutions based on the observation and analysis of the mechanisms by which living organisms, as a result of evolutionary processes spanning millions of years, have solved problems related to adaptation, locomotion, transport and structural resistance. Although biomimicry is now perceived as a sophisticated approach to engineering design, it is important to recognize that imitation is a fundamental process of human development. From early childhood, humans acquire skills related to language, social cognition, and culture through imitation mechanisms (Meltzoff & Moore, 1977), which explains why emulation of natural processes has been present since ancient times in the development of tools, materials, and structures.

The potential of biomimicry lies in the fact that living organisms offer models that are highly optimized by natural selection. Representative examples of this impact can be found in widely known applications, such as Velcro, superhydrophobic surfaces or the aerodynamic design of bullet trains, inspired respectively by the thorns of the alpine thistle, the lotus leaves and the kingfisher's beak (Bhushan, 2009). These cases illustrate how biological principles can be translated into efficient, robust and functional engineering solutions.

The formalization of the concept of biomimicry is attributed to the biophysicist Otto Schmitt, who in the 1950s developed electronic devices inspired by the propagation of nerve impulses observed in biological systems. During his research, Schmitt studied the giant nerve of the squid (Loligo), identifying an all-or-nothing response from a specific threshold.

The existence of a refractory period during which the nerve could not be excited again (Harkness, 2002). Based on these observations, he designed an electronic circuit capable of reproducing this behavior, now known as the Schmitt trigger, which introduced the concept of hysteresis by establishing differentiated thresholds of activation and deactivation (Schmitt, 1938; Schmitt, 1969). This development set a key precedent in the integration of biological principles within the design of electronic and engineering systems.

Biomimetic locomotion in nanorobotics

Locomotion at the micro and nanometric scale is one of the main challenges in the design of nanorobots, since these systems operate in regimes dominated by viscous forces, where the Reynolds number is extremely low and the inertia is negligible. Under these conditions, conventional propulsion mechanisms lose effectiveness, which forces the use of non-reciprocal strategies to generate net displacement (Purcell, 1977). Biomimicry has provided highly optimized natural models to address this problem, especially from the study of microorganisms capable of moving efficiently in viscous media (Peyer et al., 2013; Zhou et al., 2021).

Among the most consolidated biomimetic strategies is helical locomotion inspired by flagellated bacteria, such as Escherichia coli. These organisms generate propulsion through the rotation of helical flagella, converting rotational motion into translational motion even under conditions of low Reynolds number (Purcell, 1977). This principle has been widely adopted in the design of helical microrobots and nanorobots, which are currently considered one of the most representative parameters of biomimetic nanorobotics (Zhang et al., 2009; Ghosh & Fischer, 2009; Peyer et al., 2013).

The literature has shown that geometric parameters such as pitch, radius and propeller angle significantly influence the propulsive efficiency and directional stability of these systems. Consequently, numerous studies have focused on the geometric optimization of helical nanorobots based on hydrodynamic models inspired by bacterial locomotion (Zhang et al., 2009; Dong et al., 2022).

In terms of actuation and control, magnetic propulsion has established itself as the most important instrument in the world.

Dominant jib for biomimetic helical nanorobots. The application of rotating magnetic fields makes it possible to induce movement without the need for integrated energy sources, offering key advantages such as remote control, high tissue penetration and compatibility with biological environments (Peyer et al., 2013; Zhou et al., 2021). From a biomimetic perspective, this approach can be interpreted as an engineering translation of the natural flagellar rotation mechanism, in which the body's internal energy source is replaced by a controlled external stimulus (Sitti et al., 2015).

In addition to helical systems, alternative bioinspired locomotion strategies have been explored. The wave motion observed in nematode worms has been replicated in flexible microrobots designed to move in porous or highly confined media, such as biological tissues (Li et al., 2020). Likewise, pulsatile propulsion inspired by jellyfish has motivated the development of soft microrobots based on contraction and expansion cycles, although these approaches have been applied mainly at the micrometric scale (Katzschmann et al., 2018).

Finally, an emerging trend in the literature is the incorporation of principles of collective locomotion inspired by biological systems, such as bacterial swarms. In this approach, multiple nanorobots coordinate their movement to improve overall efficiency, robustness against disturbances, and the ability to perform complex tasks, which is especially relevant for engineering applications in dynamic and heterogeneous environments (Sitti et al., 2015; Li et al., 2020).

Biomimetic nanorobots with cell camouflage and biointerfaces

One of the most relevant advances in nanorobotics inspired by biomimicry has been the development of nanorobots and micromotors coated with cell membranes, a strategy that seeks to directly mimic the functional properties of biological cells. This approach arises as a response to one of the main challenges of applied nanorobotics: efficient and safe interaction with biological environments, where phenomena such as the immune response, biofouling, and rapid elimination of the system limit its performance (Zhang et al., 2018; Zhou et al., 2021).

Cell camouflage consists of coating synthetic structures with membranes derived from natural cells—such as erythrocytes, platelets, or cancer cells—while preserving proteins, receptors, and surface markers. In this way, nanorobots acquire biomimetic properties as biocompatibility, evasion of the immune system and specific recognition capacity, without compromising its locomotion or external control functions (Hu et al., 2015; Li et al., 2018).

Among the most representative examples are helical magnetic nanorobots coated with platelet membranes, which combine biomimetic locomotion with advanced biological functions. These systems have demonstrated the ability to selectively bind to circulating toxins, bacteria, or pathogens, taking advantage of platelets' natural adhesion mechanisms, positioning them as promising platforms for biomedical engineering applications, such as pathogen neutralization and targeted transport (Li et al., 2018).

Similarly, the use of erythrocyte membranes has made it possible to extend the circulation time of nanorobots in the bloodstream, reducing their recognition by macrophages and other components of the immune system. This biomimetic strategy has been widely explored in nanomedicine and, more recently, transferred to the design of mobile micromotors and nanorobots, consolidating itself as an emerging trend in the field (Hu et al., 2015; Zhao et al., 2023).

Beyond passive camouflage, biomimetic biointerfaces have opened up the possibility of integrating active functionality, such as molecular recognition, selective adhesion and response to stimuli in the environment. From an engineering perspective, these systems represent a direct convergence between nanotechnology, biomimicry, and robotics, where biological properties not only inspire the design, but are physically incorporated as functional components of the nanorobot (Zhou et al., 2021; Ahmed et al., 2023).

Together, cell camouflage and the development of biomimetic biointerfaces constitute one of the most promising lines of current nanorobotics, allowing the design of mobile systems capable of operating more efficiently, specifically and prolongedly in complex biological environments, significantly expanding the scope of their applications in biomedical engineering.

Engineering Applications and Emerging Trends in Biomimetic Nanorobots

Biomimicry-inspired nanorobotics has evolved from conceptual demonstrations to engineering applications with a high potential for impact, especially in complex biological environments. The combination of bio-inspired locomotion mechanisms, remote control strategies and functional biointerfaces has allowed the development of mobile platforms capable of re-specific tasks such as directed transport, precise navigation and localised action (Sitti et al., 2015; Zhou et al., 2021).

One of the most explored applications in the literature is targeted drug delivery, where biomimetic nanorobots take advantage of microorganism-inspired locomotion principles to access hard-to-reach regions. In this context, magnetically controlled helical systems have demonstrated the ability to move in viscous media, move against currents and position themselves precisely, which contributes to improving therapeutic efficiency and reducing side effects associated with conventional treatments (Peyer et al., 2013; Li et al., 2020). The incorporation of biomimetic coatings, such as cell membranes, has reinforced this approach by increasing biocompatibility and prolonging circulation time in the organism (Hu et al., 2015; Zhang et al., 2018).

In parallel, the literature reports a growing interest in applications related to minimally invasive surgery and micromanipulation at the micro and nanoscale. Biomimetic inspiration has guided the design of systems capable of moving in highly confined spaces and executing controlled movements with high precision, which is especially relevant for localized procedures with minimal tissue damage. Although many of these platforms currently operate at the micrometer scale, bioinspired design principles are directly transferable to nanorobotics (Sitti et al., 2015; Dong et al., 2022).

Likewise, the integration of mobile sensing capabilities represents another line of application of interest. By combining biomimetic mobility with molecular recognition elements, nanorobots can function as active sensors capable of exploring biological environments and collecting localized information. This approach shows a convergence between nanorobotics, biomimetics, and diagnostic systems, with potential for applications in early detection and in-situ monitoring (Zhou et al., 2021; Ahmed et al., 2023).

In addition to these trends, there is a notable growth in alternative action routes that expand the functional repertoire of biomimetic nanorobots. In particular, acoustic actuation (mainly by ultrasound) has positioned itself as one of the most attractive emerging strategies due to its wireless nature, its remote control capacity and its potential for operation in complex biological media. Recent literature highlights that acoustic fields they allow micro/nanoswimmers to be driven and manipulated with good dynamic response, enabling applications such as directed transport, navigation in microenvironments and micromanipulation, while introducing engineering challenges associated with robot design, coupling with the environment and optimisation of the excitation system (transducers, frequency and field patterns) (Wu et al., 2024; Xiao et al., 2022; Cao et al., 2024).

In parallel, biohybrid systems represent a direct convergence between biomimicry and nanorobotics by incorporating living organisms or biological components as functional elements of the system. This line takes advantage of natural capacities such as motility, response to stimuli and adaptability, combining them with control and functionalization strategies typical of engineering for tasks such as navigation, directed delivery, sensing and active therapies. In particular, bacteria-based microrobots have gained relevance due to their potential for integration with synthetic biology and remote control approaches, although challenges related to safety, reproducibility, and clinical translation persist (Totter et al., 2025). Likewise, bacteria-hybrid platforms with advanced functions for collective perception and guided treatment have been reported, evidencing the potential of these systems as biomedical engineering solutions (Chen et al., 2022). In a complementary way, biohybrid robots based on microalgae have been proposed as alternatives where biological locomotion and the functionalization of materials allow to expand the range of applications, both biomedical and environmental (Zhang et al., 2024).

Finally, electrical actuation emerges as an emerging route for the control of micro/nanorobots, with potential advantages in modulation, integration with electronic systems and coordination of functions such as movement and controlled release. However, recent literature also points to limitations associated with the operating environment, the complexity of control in physiological conditions and design constraints at micro/nano scale, posing clear opportunities for hybrid approaches and for the development of more robust architectures geared towards engineering applications (Pu et al., 2024).

Finally, recent literature highlights emerging trends aimed at collective behavior and the functional scalability of these systems. Inspired by bacterial colonies and distributed biological systems, several studies explore the use of swarms of nanorobots capable of coordinating their movement to improve robustness, efficiency and the ability to perform cooperative tasks, such as joint transport or distributed exploration (Sitti et al., 2015; Li et al., 2020). In a complementary way, strategies such as self-assembly and integration between nano and macro scales are emerging as key approaches to expand the functional scope of biomimetic nanorobotics, allowing the design of hierarchical architectures with more complex engineering applications (Ahmed et al., 2023).

Together, these advances show that biomimicry-inspired nanorobotics is in a stage of consolidation, in which biological inspiration not only guides the design, but enables more efficient, adaptable and functional engineering solutions to operate in highly challenging environments.

CONCLUSIONS

Biomimicry-inspired nanorobotics has established itself as a rapidly evolving interdisciplinary field of research, in which principles derived from biological systems have made it possible to address fundamental challenges associated with operation at the micro and nanometer scale. Throughout this review, it has been shown that biomimicry not only acts as a source of conceptual inspiration, but also as a functional framework for the design of nanorobots capable of efficient locomotion, controlled interaction with complex environments and adaptation to adverse biological conditions.

State-of-the-art analysis shows that the most recent advances are concentrated in bio-inspired locomotion strategies, particularly those based on flagellated microorganisms, where helical geometry and magnetic actuation have emerged as robust and widely adopted solutions. These approaches have proven to be especially effective in regions dominated by viscous forces, consolidating themselves as one of the most mature and promising lines of current nanorobotics. In addition, the development of nanorobots coated with cell membranes represents an emerging trend of high impact, as it directly integrates biological properties such as biocompatibility, evasion of the immune system and specific recognition, significantly expanding the possibilities of application in biomedical environments.

From an engineering perspective, this review highlights the close relationship between nanotechnology, nanostructures and biomimetics in the development of functional solutions. The translation of natural mechanisms, such as flagellar rotation, cell adhesion or collective organization, into controllable artificial systems has made it possible to design nanorobotic platforms with greater efficiency, precision and adaptability. In this sense, biomimicry acts as a bridge between the understanding of biological phenomena and their implementation in engineering devices capable of operating in conditions where traditional approaches are limited.

The synthesis of the main findings highlights that engineering applications are the main driver of progress in biomimetic nanorobotics, highlighting areas such as targeted drug delivery, minimally invasive surgery, mobile sensing and cooperative swarm-type systems. However, despite the progress made, relevant challenges remain related to scalability, precise control in dynamic environments, the integration of multiple functions in a single system, and the transition from experimental demonstrations to practical applications.

Overall, the revised results indicate that biomimicry-inspired nanorobotics is in a consolidation phase, with solid scientific foundations and clear potential for growth. The continued convergence of biology, nanotechnology and engineering disciplines suggests that future developments will be geared towards more autonomous, multifunctional and cooperative systems, capable of making more profound use of biological principles to solve complex problems. In this context, biomimicry is emerging not only as a design strategy, but as an essential component for the sustainable and functional advancement of nanorobotics.

REFERENCES

1. [National Nanotechnology Initiative, 2025] National Nanotechnology Initiative (NNI) (2025). What is Nanotechnology? (Nanotech 101). nano.gov. https://www.nano.gov/nanotech-101/ what/definition ↑Ver página
2. [Himel et al., 2023] Himel, M. H., Sikder, B., Ahmed, T., & Choudhury, S. M. (2023). Biomimicry in nanotechnology: a comprehensive review. Nanoscale Advances, 5, 596–614. https://doi.org/ 10.1039/D2NA00571A ↑Ver página
3. [Feynman, 1992] Feynman, R. P. (1992). There's plenty of room at the bottom (data storage). Jour- nal of Microelectromechanical Systems, 1(1), 60–66. https://doi.org/10.1109/84.128057 ↑Ver página
4. [Choi et al., 2015] Choi, C., Kang, D., & Park, J. (2015). Bioinspired design of nanomaterials and sys- tems. Advanced Materials. https://doi.org/10.1002/adma.201501251 ↑Ver página
5. [Bhushan, 2009] Bhushan, B. (2009). Biomimetics: lessons from nature—an overview. Philosophical Transactions of the Royal Society A, 367(1893), 1445–1486. https://doi.org/10.1098/rsta. 2009.0011 ↑Ver página
6. [Harkness, 2002] Harkness, J. (2002). Otto Schmitt and the making of biomimetics. IEEE Enginee- ring in Medicine and Biology Magazine, 21(4), 64–72. https://doi.org/10.1109/MEMB.2002. 1032639 ↑Ver página
7. [Meltzoff & Moore, 1977] Meltzoff, A. N., & Moore, M. K. (1977). Imitation of facial and manual ges- tures by human neonates. Science, 198(4312), 75–78. https://doi.org/10.1126/science. 198.4312.75 ↑Ver página
8. [Schmitt, 1938] Schmitt, O. H. (1938). A thermionic trigger. Journal of Scientific Instruments, 15(1), 24–
9. 26. https://doi.org/10.1088/0950-7671/15/1/305 ↑View Page
10. [Purcell, 1977] Purcell, E. M. (1977). Life at low Reynolds number. American Journal

of Physics, 45(1), 3–11. https://doi.org/10.1119/1.10903 ↑View page

11. [Zhang et al., 2009] Zhang, L., Abbott, J. J., Dong, L., Peyer, K. E., Kratochvil, B. E., Zhang, H., Berge- les, C., & Nelson, B. J. (2009). Artificial bacterial flagella: Fabrication and magnetic control. Nano Letters, 9(10), 3663–3667. https://doi.org/10.1021/nl803830x ↑Ver página
12. [Ghosh & Fischer, 2009] Ghosh, A., & Fischer, P. (2009). Controlled propulsion of artificial mag- netic nanostructured propellers. Nano Letters, 9(6), 2243–2245. https://doi.org/10.1021/ nl900186w ↑Ver página
13. [Peyer et al., 2013] Peyer, K. E., Zhang, L., & Nelson, B. J. (2013). Bio-inspired magnetic swimming mi- crorobots for biomedical applications. Nanoscale, 5(4), 1259–1272. https://doi.org/10.1039/ C2NR32554C ↑Ver página
14. [Wu et al., 2024] Wu, G., Xian, W., You, Q., Zhang, J., & Chen, X. (2024). AcousticRobots: Smart acous- tically powered micro-/nanoswimmers for precise biomedical applications. Advanced Drug Deli- very Reviews, 207, 115201. https://doi.org/10.1016/j.addr.2024.115201 ↑Ver página
15. [Zhou et al., 2021] Zhou, H., Mayorga-Martinez, C. C., Pané, S., Zhang, L., & Pumera, M. (2021). Mag- netically driven micro and nanorobots. Chemical Reviews, 121(8), 4999–5041. https://doi.org/ 10.1021/acs.chemrev.0c01234 ↑Ver página
16. [Dong et al., 2022] Dong, Y., Wang, X., & Zhang, L. (2022). Magnetic helical micro-/nanomachines: Recent progress and perspective. Matter, 5(1), 77–109. https://doi.org/10.1016/j.matt. 2021.10.010 ↑Ver página
17. [Hu et al., 2015] Hu, C.-M. J., Zhang, L., Aryal, S., Cheung, C., Fang, R. H., & Zhang, L. (2015). Erythrocyte membrane-camouflaged nanoparticles as a biomimetic delivery system. Proceedings of the National Academy of Sciences, 112(35), 10980–10985. https://doi.org/10.1073/pnas. 1501352112 ↑Ver página
18. [Zhang et al., 2018] Zhang, Q., Dehaini, D., Zhang, Y., Zhou, J., Chen, X., Zhang, L., Fang, R. H., & Zhang, L. (2018). Cell membrane–coated nanoparticles for biomedical applications. Chemical Society Reviews, 47(9), 3423–3438. https://doi.org/10.1039/C7CS00633J ↑Ver página
19. [Li et al., 2017] Li, J., Esteban-Fernández de Ávila, B., Gao, W., Zhang, L., & Wang, J. (2017). Mi- cro/nanorobots for biomedicine: Delivery, surgery, sensing, and detoxification. Science Robotics, 2, eaam6431. https://doi.org/10.1126/scirobotics.aam6431 ↑Ver página
20. [Sitti et al., 2015] Sitti, M., Ceylan, H., Hu, W., Giltinan, J., Turan, M., Yim, S., & Diller, E. (2015). Biomedical applications of untethered mobile milli/microrobots. Proceedings of the IEEE, 103(2), 205–224. https://doi.org/10.1109/JPROC.2014.2385105 ↑Ver página
21. [Li et al., 2023] Li, M., Hu, X., Zhang, Y., & Zhao, Y. (2023). An overview of recent progress in mi- cro/nanorobots for biomedical applications. Advanced Materials Technologies. https://doi.org/ 10.1002/admt.202201928 ↑Ver página
22. [Kim et al., 2024] Kim, J., & (et al.). (2024). Advanced materials for micro/nanorobotics. Chemical So- ciety Reviews. https://doi.org/10.1039/D3CS00777D ↑Ver página
23. [Yang et al., 2024] Yang, (et al.). (2024). Advanced biomimetic and biohybrid magnetic micro/nano machines. Advanced Materials Technologies. https://doi.org/10.1002/admt.202400239
24. ↑View page
25. [Cao et al., 2024] Cao, H. X., Nguyen, V. D., Park, J.-O., Choi, E., & Kang, B. (2024). Acoustic Actuators for the Manipulation of Micro/Nanorobots: State-of-the-Art and Future Outlooks. Micromachines, 15(2), 186. https://doi.org/10.3390/mi15020186 ↑Ver página
26. [Totter et al., 2025] Totter, E., von Einsiedel, E., Regazzoni, L., & Schuerle, S. (2025). Paving the way for bacteria-based drug delivery: biohybrid microrobots emerging from microrobotics and synthe- tic biology. Advanced Drug Delivery Reviews. https://doi.org/10.1016/j.addr.2025. 115577 ↑Ver página

27. [Pu et al., 2024] Pu, R., Yang, X., Mu, H., Xu, Z., & He, J. (2024). Current status and future application of electrically controlled micro/nanorobots in biomedicine. Frontiers in Bioengineering and Biotech- nology, 12, 1353660. https://doi.org/10.3389/fbioe.2024.1353660 ↑Ver página