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Bioinspiration: A Motivation for Investing in Foundational Biological Research in the U.S.

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Executive Summary

Bioinspiration is a growing field that translates biological principles into engineering solutions, often yielding significant returns even from niche research. Because bioinspired design and technologies can lead to both biological and non-biological applications, it has the potential to generate billions of dollars for the U.S. economy and contribute to millions of jobs in fields as diverse as construction, healthcare, and chemical manufacturing. To promote this economic growth, significant investment must be made across the innovation pipeline, starting from foundational biological research to commercialization. Currently, several U.S. federal agencies, such as the National Science Foundation (NSF), have programs to aid start-ups in advancing technology, business, and product development. Although private funding for bioinspired start-ups exists, support is limited, and venture capital's volatility makes securing finances difficult until products are de-risked and market ready. To maintain a thriving bioinspired innovation landscape, continued federal funding, through Congressional appropriations and subsequent grants and contracts to research and business teams, is essential.

Developing bioinspired technologies often begins with investigating biological phenomena to build a foundational understanding of the system. Researchers then develop engineering solutions that mimic or adapt those biological functions or properties. Nonetheless, supporting foundational biological research with an eye toward bioinspiration may be met with skepticism due to its unpredictable return on investment (ROI) and the extended timeline for results when bringing technology from discovery to market. However, the impact of such research and its outcomes can be significant. For example, federal funding supported the development of a model to understand how honeybees organize themselves without a leader to collect pollen. After over a decade, the original model was adapted to an algorithm to increase revenue for web hosting services. The application of this research now benefits the 5.6 billion people that use the internet and is estimated to have increased revenue for a global market with a projected worth of almost $160 billion in 2025.

In addition to the support for foundational biological research, significant funds must also be dedicated to aid bioinspired technology development through a challenging innovation landscape. Oftentimes, there is a deficit in investment to support critical product testing, validation, and scale-up because of the uncertainty of product success. To combat this challenge, federal agencies provide funding and business development support to derisk these products. Currently, over 700 bioinspired small businesses have received American seed grants through programs such as the Small Business Innovation Research (SBIR) program and Small Business Technology Transfer (STTR) program. Different phases of these programs support different stages of product development. Phase I aids in applied research and development, while Phase II focuses on subsequent development for scale-up and eventual commercialization.

Despite support from SBIR and STTR programs, start-ups may still face limited expertise for business development and commercialization. For example, many scientific researchers from academia lack the business acumen to find the right customer base for their product and to navigate processes associated with intellectual property. NSF has developed a bioinspired track for their Convergence Accelerator program to connect bioinspired start-ups to experts and potential clients, fostering consumer-focused products that address challenges in infrastructure, food production and human health. Meanwhile, programs like the Advanced Research Project Agency-Energy (ARPA-E) SCALEUP assist start-ups in overcoming costs for early commercialization of energy-oriented products and technologies. Overall, these programs are vital in providing bioinspired start-ups the necessary resources to create novel technologies that tackle complex issues. Consistent funding appropriated for these American seed programs would enable federal agencies to continue adapting their support for start-ups, offering crucial mentorship and commercialization assistance.

Although there is inherent financial risk in supporting start-ups at their earliest stages, two private institutions, the Biomimicry Institute and the Wyss Institute, have together enabled over 100 start-ups in bioinspired innovation in the U.S. These institutes help start-ups succeed by providing resources and mentorship for business development, while enabling future funding from private and government sources. However, Congress needs to supplement these efforts through its funding to federal agencies to broaden reach and increase chances of successful market entry. In fact, small businesses are five times more likely to get outside investment after receiving an NSF seed award, further underscoring the importance of federal investment in supporting bioinspired innovation. To ensure U.S. dominance globally in scientific discovery and the worldwide economy, it is crucial that policymakers continue their support of funding foundational biological research and its translation to bioinspired breakthroughs.

Introduction

Bioinspiration illustrates how even obscure biological research can lead to big impact, offering major returns on investment in terms of product or other economic value and employment creation. Bioinspired products are materials, systems, tools, and other engineered designs that draw ideas from structures, systems, and processes found in nature. Bioinspiration has led to materials such as Velcro, the design and orientation of solar arrays, and the function of navigation systems.[1–3] The development of bioinspired products hinges on advancements and applications from foundational biological research that aims to understand organisms, their adaptations, and their environmental interactions. Both foundational research and bioinspired technology development depend on funds that Congress appropriates to federal agencies to create grants and programs to support the research and aid technology and business development. The innovations resulting from federal grants and programs have significant potential to fuel job and industry growth. A report released in 2015 suggested that biomimicry activities could account for as much as $425 billion in gross domestic product (GDP; valued in 2013 dollars) of the United States and $1.6 trillion of global output by 2030, while adding up to two million U.S. jobs in sectors as diverse as transportation, electronics, and food manufacturing.[4–6] While this economic and societal potential is significant, the benefits of studying organismal mechanics or behavior as they lead to bioinspired products may not be immediately obvious or quick to come to fruition, making the connection of research-to-impacts unclear.

The uncertainty of possible applications and the length of time from research to product can make it difficult to justify funding for foundational biological research that might serve as bioinspiration. Federal agencies, independently from Congress, make decisions about which research to fund based on the expertise of the research team, the feasibility of the project, and the proposed implications reported via grant applications from researchers, making Congress some steps removed from the funding process. Despite this, investing in foundational research into biological properties and functions as potential bioinspiration can present opportunities for innovation across various sectors such as sustainability, information technology, materials, and national defense. For example, despite being criticized as 'a waste of taxpayers' funds,' scientists studying eyelash length successfully defended the value of the research by developing protection for optical sensors and solar panels.[7–9] This example highlights why even the most obscure topics deserve to be studied, as they can have far reaching applications.

Beyond justifying the value of basic biological research for bioinspiration, further challenges arise in the transition of basic research to products during the "innovation valley of death," where there is a deficit in funding due to the high risk of failing to reach commercialization. To bridge the gap from initial biological research to the final bioinspired product, government seed grants and targeted private investment can provide non-dilutive funding for product conception, testing, development, and scale-up. U.S. Government programs, such as the Small Business Innovation Research (SBIR) program, exist because of the high risk of failure at the product ideation and development phases that makes it less likely for start-ups to get funding from venture capital. Programs such as the National Science Foundation's Innovations Corps and Convergence Accelerator provide resources, including networking opportunities, entrepreneurial training, and funding to test ideas and prototypes that strengthen the launch of novel technologies. Private organizations, such as the Biomimicry Institute, also provide services aimed at start-ups, although the support they provide is not available or distributed across the U.S. and can be limited to certain affiliations or individuals, restricting their impact. Altogether, federally funded programs are crucial for researchers to identify the appropriate market(s) for breakthroughs and for funding organizations to achieve their strategic goals. Therefore, continued or even increased support from Congress to federal agencies to invest in foundational biological research and ensuing bioinspired design is necessary and important for technology development, product discovery, and economic benefit.

The Many Different Paths from Biology to Solution

To be considered bioinspired, research and innovation must draw inspiration from biological systems, structures, materials, behaviors, or processes observed in nature, to develop human-made solutions which replicate or adapt those biological functions or properties. The link between the biological inspiration and the product or solution can be clear, such as taking advantage of the strength, flexibility, and biocompatibility of spider silk for sutures in surgery.[10,11]

Alternatively, the biological inspiration and solution can be more indirectly observed, such as neural networks in artificial intelligence based on the neural pathways in the human brain.[12,13]

There are many different forms of bioinspiration, delineated by how much the design reflects the system it was originally inspired from. For instance, biomimicry, a subdiscipline of bioinspiration, is a more direct connection between the biology and the engineered outcome. Creating a robot that flies exactly like a bird by directly mimicking its wing structure and movement is an example of biomimicry, while other forms of bioinspiration might use a bird's aerodynamic principles to inform the design of more efficient wings, such as for airplanes. Bioinspired designs can also lead to common materials, machinery, or other technology that might not have any obvious elements of biology. For example, Velcro was inspired by burdock burrs sticking onto dog fur.[1] The burrs of the burdock are similar to a threading needle, which allows the burr to hook onto hair and fur for seed dispersal.[14] The Japanese Shinkansen train was inspired by how a kingfisher dives into the water to hunt.[15] Due to the shape of the kingfisher's head and beak, there is decreased resistance and minimal splash when entering the water; the front of the Shinkansen train replicates this shape to reduce drag and avoid sonic booms when these high-speed trains enter tunnels. Bioinspiration illustrates how biological research, across all its subdisciplines, can sometimes lead to unexpected innovations and societal benefits, many of which are outside the field of biology.

Before biology becomes a bioinspired product, it usually starts as foundational research that aims to gather a general understanding of a biological system or phenomena, rather than through intention to engineer or design a solution. Indeed, the bioinspired product may arrive far in the future, where another researcher adapts the system for a separate (often) non-biological purpose. However, since the benefits of foundational research can ultimately be transformative, Congress, through the appropriations process, should remain open to the various kinds of application-diverse or -agnostic research federal agencies may support. Each year, Congress allocates specific funding to agencies, and once those budgets are enacted, agencies are able to invest in research programs and projects through grants, contracts, and other mechanisms

Example 1. The Impact of Foundational Research: The Honeybee Algorithm. Researchers developed a model to replicate the behavior of bee swarms with the goal of understanding how bees organize themselves to collect nectar and store without a leader.[a,b] However, it would take over a decade for researchers to adapt the model to increase revenue for web hosting services, by adapting server activity to website traffic,[c,d] an impact that can be felt by every individual that uses the internet, over 5.6 billion people.[e] Because of possible slow and uncertain returns on investment, funders may hesitate to support bioinspired projects. Nevertheless, initial investment by the U.S. National Science Foundation (NSF), the Department of Defense (DoD) Office of Naval Research (ONR), and the Department of Agriculture (USDA) was vital in understanding honeybee communication during foraging and honey storage, which in turn enabled the development of the algorithm.[a,b] This funding from the federal Government for the foundational research has thus resulted in an application with benefits for a global market that is projected to reach almost $160 billion in 2025.[f] These significant outcomes led to the researchers winning the Golden Goose Award* in 2016 for the significant societal impact derived from rather remote foundational research.[g,h] This case underscores the crucial role agencies like NSF play in funding foundational research to address national and global needs, aligning with NSF's mission to "promote the progress of science; advance national health, prosperity and welfare; and secure national defense."[i]

*The Golden Goose Award, founded in 2012 as inspired by U.S. Representative Jim Cooper, highlights foundational research that initially seems obscure, yet has had major societal impact. The Golden Goose Award was created as a counter to an earlier award, The Golden Fleece Award (1975-88), which intended to expose and mock federal science funding that U.S. Senator William Proxmire considered wasteful.[g]

[a]Bartholdi JJ, Seeley TD, Tovey CA, Vate JHV. The Pattern and Effectiveness of Forager Allocation Among Flower Patches by Honey Bee Colonies. *Journal of Theoretical Biology* . 1993;160(1):23-40. doi:10.1006/jtbi.1993.1002; [b]Seeley TD, Tovey CA. Why search time to find a food-storer bee accurately indicates the relative rates of nectar collecting and nectar processing in honey bee colonies. *Animal Behaviour* . 1994;47(2):311-316. doi:10.1006/anbe.1994.1044; [c]Nakrani S, Tovey C. On Honey Bees and Dynamic Server Allocation in Internet Hosting Centers. *Adaptive Behavior - ADAPT BEHAV* . 2004;12:223-240. doi:10.1177/105971230401200308; [d]Tovey C. HONEY BEE Algorithm: A Biologically Inspired Approach to Internet Server Optimization. *The honey bee algorithm: A biological inspired approach to internet server optimization* . Published online January 1, 2004:13-15.; [e]Kumar N. 22 Internet Usage Statistics 2025 [Worldwide Data]. DemandSage. September 2, 2025. Accessed November 21, 2025. https://www.demandsage.com/internet-user-statistics/; [f]Sharma M. Ultimate Web Hosting Statistics and Market Share Report (2025). Bluehost Blog. September 5, 2024. Accessed November 21, 2025. https://www.bluehost.com/blog/web-hosting-statistics-market-share/; [g]History. The Golden Goose Award. Accessed November 21, 2025. https://www.goldengooseaward.org/history; [h]Shiode J. 2016: The Honey Bee Algorithm. The Golden Goose Award. September 14, 2016. Accessed November 21, 2025. https://www.goldengooseaward.org/01awardees/honey-bee-algorithm; [i]About NSF | NSF - U.S. National Science Foundation. Accessed November 21, 2025. https://www.nsf.gov/about

that advance their missions.[16] The budget guidance from Congress is often, and necessarily, unspecific when it comes to the distinct science and engineering research that gets funded. This structure allows agencies to pursue long-term, curiosity-driven work with the potential to inspire future technologies. This in turn is what enables a decade of bee foraging research to lead to a web hosting algorithm with significant societal impact (Example 1). With continued Congressional support, federal agencies can maintain their autonomy to invest in foundational biological research that supports their mission.

Supporting the Translation of Foundational Research to Product

While biological inspiration can fuel innovation, translating research into viable products requires sustained investment for foundational research to reach commercialization. Congressional support for bioinspired research and development enables federal agencies to fund efforts across the innovation landscape. After critical discoveries are made at the foundational research stage, scientists can expand their research into the next phases of the innovation pipeline. Funding is especially crucial during the next phases as projects enter the innovation valley of death,[17] where there is historically not enough investment to support critical product testing, validation, development, and scale-up (Figure 1). In the U.S., the federal government mainly focuses on supporting foundational research and early-stage translation/pilot research, anticipating private funding beyond this initial phase. However, private companies and funders, such as venture capital, may be unwilling to invest in a product or technology's development without knowing if it is market viable and scalable. This results in a gap in support (the valley of death) where neither federal funding nor private funding is easy to procure. Funding targeted to these stages is necessary, not only to support technology development but also business development such as ideation, networking and building industry connections, and evaluating the supply chain.

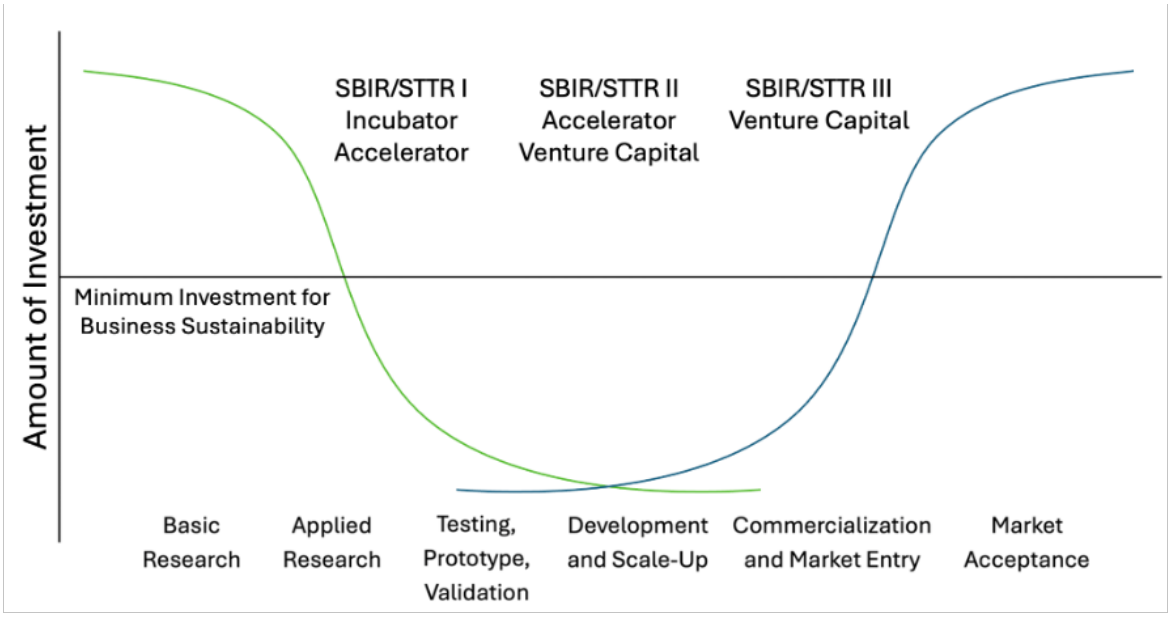

Figure 1: Innovation Valley of Death and Possible Funding Sources. Consistent funding and investment are necessary throughout the innovation lifecycle. Private and federal funding, such as SBIR/STTR grants and loans or venture capital investment, at targeted points in the lifecycle can alleviate deficits arising from the costs of applied research and development, helping businesses survive the innovation valley of death. This figure was modeled from Idea to Value, with the addition of funding types shown at different stages of the innovation valley of death.[18]

To promote bioinspired innovation, additional investment is necessary to remedy this deficit and derisk products. The U.S. government is one of the few bodies able to dedicate significant funding, while taking on such risk. Currently, the federal government provides seed grants to support small businesses to conduct applied research and development of a high-potential technology through feasibility, prototyping, and early commercialization.[19] The federal government also

has incubator programs to promote product inception and initial growth of start-ups and accelerator programs to speed start-up growth during the testing and development phases. In addition to funding, incubators and accelerators often provide business training, networking opportunities, and additional resources. After this bridging support needed to derisk product development, venture capital then has the confidence to fund those start-ups through commercialization and market entry. This landscape ultimately enables bioinspired innovation to cross the valley of death and enter the market as the goods and services that help society and provide economic output (Example 2).

Example 2. U.S Government Support for Medical Devices Inspired by Shark Skin. Scentists funded by the DoD Office of Naval Research and the National Institutes of Health (NIH) developed materials inspired by shark skin anti-fouling properties that prevent spore attachment and growth.[a,b] Suspecting that the patterning of shark skin prevents fouling, researchers created a material, Sharklet AF™, which mimics the microscale topography.[a,c] While answering the question as to why a shark's skin is clean, the researchers also recognized that the materials have both biomedical and naval transport applications. Because of the project's initial success, the researchers started a company, Sharklet Technologies Inc., in 2007 in Aurora, Colorado. Over the course of 10 years, the company was granted 11 SBIR awards from NIH, for a total of $8.8 million.[d] In 2017, Sharklet was acquired by a large firm, Peaceful Union, and has since developed films, catheters, endotracheal tubes, and even yoga mats.[e]

[a]Technology Overview. Sharklet Technologies, Inc. Accessed November 21, 2025. https://www.sharklet.com/technology-overview/; [b]Sullivan T, Regan F. The characterization, replication and testing of dermal denticles of Scyliorhinus canicula for physical mechanisms of biofouling prevention. *Bioinspir Biomim* . 2011;6(4):046001. doi:10.1088/1748-3182/6/4/046001; [c]Carman ML, Estes TG, Feinberg AW, et al. Engineered antifouling microtopographies – correlating wettability with cell attachment. *Biofouling* . 2006;22(1):11-21. doi:10.1080/08927010500484854; [d]Firm | SBIR. Accessed November 24, 2025. https://www.sbir.gov/portfolio/410655; [e]How Shark Skin Inspired an Antibacterial Surface Technology. Medical Device and Diagnostic Industry. Accessed November 24, 2025. https://www.mddionline.com/rd/how-shark-skin-inspired-an-antibacterial-surface-technology

Bioinspired products can be a major return on investment (ROI) into biological research and its conversion into applied developments in many other fields, from materials science and chemistry to robotics and telecommunications. Of the $425 billion anticipated to be added to the U.S. economy by 2030 from bioinspired innovations, the biggest impacts are expected to be in building construction and the chemical industry, with a potential added value of about $70 billion each to the U.S. GDP.[6,20] This potential economic value from bioinnovation is possible because of federal government investment in foundational biological research and continued allocation of funding for small businesses to bring their products to market.

American Seed Funds: Bridging the Valley of Death from Applied Research to Products

As research progresses from foundational investigations to the applied stage and toward scale-up, the science and collaborations that must be integrated into the development process expand. This expansion requires more knowledge, resources, and manpower to continue product testing, development, and scale-up. Acquiring and sustaining these resources is a common challenge for start-ups and early-stage launches, as they need enough investment to overcome the innovation valley of death. The challenge of obtaining funds can be exacerbated by the volatility of venture capital, which fluctuates due to changes in the market or can be difficult to sustain over the time it takes for product development.[21,22]

Recognizing the issue, several U.S. government agencies provide seed funds, such as through the SBIR and STTR programs. These grant programs have proven crucial for securing the capital required to bring products to market scale. This capital facilitates the acquisition of diverse research expertise and techniques, bridging biological concepts with engineering designs. Start-ups and small businesses looking to test and develop their bioinspired goods and services can apply to obtain SBIR/STTR grants through submitting a contract proposal or grant application.[23] Eleven U.S. government agencies support SBIR grants, with seven of those also supporting STTR grants.[24] The major difference between SBIR and STTR grants is that STTR grants require a partnership with a non-profit research institution and the eventual technology transfer from the institution to the small business.[19,25] Aside from this difference, both grants can be offered in two phases: Phase I grants are for start-ups and small businesses to conduct applied research and development and/or feasibility studies to

determine scientific and technical merit and viability of the proposed bioinspired product or service;[23] Phase II grants focus on continued development for the goal of scale-up and potential commercialization.[23] As the products from start-ups reach development and scale-up and the risk of market failure declines, the role of the U.S. government diminishes, resulting in the funding of far fewer Phase II grants. For example, NSF estimated that it will fund about 240 SBIR/STTR Phase I grants, but only 45 Phase II grants for 2025.[26] In rare cases, there are Phase III grants directed towards scale-up and commercialization, but these grants are supported by federal capital outside of SBIR and STTR funding sources and are generally awarded if the product is intended for government use.[23,27]

Together, these government funding structures not only support technological development, but also generate measurable outcomes, which are reflected in the economic effects of SBIR and STTR investments. SBIR and STTR grants have demonstrated a substantial ROI for the U.S. economy. For example, the Department of Health and Human Services' National Cancer Institute analyzed 690 Phase II awards from 1998-2010 and found a total ROI of 260% from resulting technology sales. This analysis also attributed the creation of 108,000 new jobs by 2018 to these awards.[28] More notably, more than 16,000 Department of Defense Phase II awards issued from 1995–2012 generated an ROI of 2200% and contributed 1.5 million jobs by 2018.[29] Beyond their economic impact, these federal seed grants provide critical support for start-ups developing high-risk technologies. The National Academies reported that over 70% of SBIR- and STTR-funded projects would likely, or certainly, not have continued without federal investment, underscoring the essential role these programs play in advancing start-up development in the U.S.[30]

Funding from SBIR and STTR grants has enabled a wide range of innovative projects, including a significant number rooted in bioinspired design. Over 700 projects sponsored by government seed funds since 2000 have made specific reference to bioinspiration in some form, although this is likely an undercount, as many projects could be bioinspired without stating the connection (see Supplemental Data). Some select examples of projects incorporating bioinspiration can be found in Table 1. Bioinspired SBIR and STTR projects include solar cells inspired by plants' mechanical response to light,[2,31] pitcher plant-inspired surgical implants for ear infections,[32–34] and renewable energy inspired by the mechanics of fish swimming.[35–37] Because of continued Congressional support for American seed grants, government spending has enabled a wide breadth of bioinspired projects, and provided a strong lifeline for business innovation in the U.S.

While SBIR and STTR grants are a much-needed lifeline to support start-ups and small businesses to overcome the valley of death, the drawbacks due to funding delays and program limitations can slow down innovation progress. For example, there is often a delay in transition of SBIR/STTR grants from Phase I to Phase II due to eligibility requirements, the number of applications an agency receives to review, and the time it takes to approve and allocate funds.[38,39] This setback can lead to financial losses, research and development stagnation, supply stock shortages, and reduced market competitiveness. Also, further delays can occur when commercializing the product through the government (such as through a Phase III award). Another drawback of traditional SBIR and STTR grants is the lack of resources normally provided to teach start-ups and small businesses how to commercialize their product.[40] Once the product is fully developed, a bioinspired start-up may either have difficulty identifying the appropriate market (e.g. identifying key stakeholders or the procurement process) or may have an initial intended customer base that is no longer viable, necessitating a pivot.

To prevent time gaps, agencies have created workarounds. For example, ARPA-E has instituted combined grants to eliminate the time lost during the transition period from Phase I to Phase II (Example 3). Other agencies, such as NSF, provide opportunities in which a start-up with a high chance of product commercialization can submit a FastTrack application to receive Phase I and Phase II grants simultaneously.[41] Agencies have also created transition programs for commercialization, such as the Department of Defense Office of the Navy SBIR Transition Program,[42] the Department of Health and Human Services' National Institute of Health Commercialization Readiness Pilot Program,[43] and the Department of Energy Technical and Business Assistance Services.[44] These programs were created to tackle challenges in commercialization faced by SBIR/STTR award recipients. By providing collaborations, third-party assistance, and other resources, these programs can help start-ups find the right clientele to sell their product. Consistent funding for SBIR/STTR programs, and additional investments in programs that enable market exploration and the development of

commercialization strategies, allow agencies within the U.S. government to continue supporting bioinspired small businesses from testing to development while also pursuing the government's strategic goals through this investment, like sustainability and energy dominance, and adding value to the economy. Therefore, continued support of the SBIR and STTR programs by Congress through sustained or even increased appropriations will enable federal agencies to fund bioinspired start-ups in line with their missions.

Table 1: Examples of Bioinspired Projects Supported by American Seed Funds.

Inspiration	Product	Principle	Agency	Program
Delayed stall in flyers	Fans, compressors	Fluid dynamics	DOD	SBIR II
Gecko foot	Dry adhesive	Materials	DOD	SBIR II
Jellyfish propulsion	Profiling float	Fluid dynamics	DOD	STTR I
Neural network	Sensor/classifier for low signal threats	Data/computing, microelectronics	DOD	STTR II
Bird flight	Fly-by-feel systems for autonomous aircrafts	Mechanics, thermal	DOD	STTR II
Insects and crotalid snakes	Wide field of view imaging sensors	Optics/photonics	DOD	STTR II
Fish swimming, electrosense, magnetosense	Magnetoelectrosensory navigation system	Electromagnetism	DOD	STTR II
Antifreeze peptide/protein	Biomimetic antifreeze	Chemical	DOD/NSF/ NIH	SBIR II
Fish swimming	Hydrokinetic renewable energy	Energy	ARPA-E	SBIR II
Trees and bees	3D corrugated wood	Materials	ARPA-E	SBIR II
Spider's body	Wind turbine float	Energy, materials	ARPA-E	SBIR II
Spiroligomers	Biomimetic enzymes	Chemical	DOE	STTR II
Hair fibers, receptor neurons	Shear sensor array	Mechanics	NASA	SBIR I
Arapaima gigas fish	Space suits for lunar dust abrasion	Materials	NASA	STTR I
Plant nyctinasty	Solar arrays	Energy	NASA	STTR I
Shark skin	Anti-fouling materials	Materials	NIH	SBIR II
Synovial fluid	Biomimetic lubricant	Chemical	NIH	SBIR I
Pitcher plants	Tympanostomy tubes	Biomedical	NIH	SBIR I
Red blood cells	Blood substitute	Biomedical	NIH	SBIR II
Keratin	Plastic	Materials	NSF	SBIR I
Plant heliotropism	Kirigami solar cells	Energy, materials	NSF	CA
Plant roots	Anchor system	Mechanics	NSF	I-Corps
Leafhopper brochosome	Multipurpose optical coating	Chemical, optics/photonics	NSF	I-Corps
Cartilage lubrication	Synthetic meniscus	Biomedical	NSF	I-Corps
Water channel protein	Membranes	Materials	NSF	I-Corps
Mushrooms	Redox flow batteries	Energy	NSF	I-Corps

This list was produced from America's Seed Fund award search for terms related to bioinspiration (see Supplemental Data), demonstrating the diverse impact bioinspiration has within and outside of biology. Columns from left to right identify the inspiration found in nature, resulting product or technology, and the underlying scientific principle or research field; the federal agencies and funding programs demonstrate the different pathways through which the U.S. government supports the bioinspired innovation landscape.

Example 3. SBIR Grant Supports Development of More Sustainable Building Materials. Within the U.S. Department of Energy (DoE), the Advanced Research Project Agency - Energy (ARPA-E) often funds projects with a combined SBIR Phases I and II grant to aid start-ups with high societal potential to progress from testing to scale-up.[a] Recently, ARPA-E funded a project through a combined SBIR grant to develop 3D corrugated wood with a honeycomb structure to replace less sustainable building materials.[b] After treating the wood, scientists are able to fold and mold the wood to its desired shape. The result is a material that has similar strength to aluminum alloys, but at one-fourteenth the cost, one-third the density, and with CO_2 emissions reduced by 90% during manufacturing.[b-d] Due to the success of the product, ARPA-E provided subsequent funding through its SCALEUP Program to assist in surmounting costs for early commercialization.[e-g] Because of the support provided by ARPA-E, the start-up InventWood Inc.—currently based in Frederick, Maryland—has 144 patents filed, 41 patents granted, and entered the market in summer 2025.[h-n] Government grants and contracts can be key in maintaining progress and keeping start-ups afloat as they work to finalize their products and enable production at mass- or market-scale. Furthermore, SBIR and STTR awards are a crucial way for ARPA-E to achieve its goals of reducing energy imports, reducing emissions, improving infrastructure, improving energy efficiency, and/or creating nuclear fuel and waste solutions.

[a]Committee on the Review of the Small Business Innovation Research and Small Business Technology Transfer Programs at the Department of Energy, Board on Science, Technology, and Economic Policy, Policy and Global Affairs, National Academies of Sciences, Engineering, and Medicine. *Review of the SBIR and STTR Programs at the Department of Energy* . National Academies Press; 2020:25674. doi:10.17226/25674; [b]Wood Honeycombs for Lightweight, Energy Efficient Structural Applications | ARPA-E. Accessed November 24, 2025. https://arpa-e.energy.gov/programs-and-initiatives/search-all-projects/wood-honeycombs-lightweight-energy-efficient-structural-applications; [c]Xiao S, Chen C, Xia Q, et al. Lightweight, strong, moldable wood via cell wall engineering as a sustainable structural material. *Science* . 2021;374(6566):465-471. doi:10.1126/science.abg9556; [d]InventWood — Technology. Accessed November 24, 2025. https://www.inventwood.com/technology; [e]Energy Secretary and Maryland Governor visit with MEI2 startups. Accessed November 24, 2025. https://energy.umd.edu/news/story/energy-secretary-and-maryland-governor-visit-with-mei2-startups; [f]Home. Accessed November 24, 2025. https://impel.lbl.gov/home; gSCALEUP Program | ARPA-E. Accessed December 23, 2025. https://arpa-e.energy.gov/programs-and-initiatives/SCALEUP-program; [h]InventWood — About. Accessed November 24, 2025. https://www.inventwood.com/about; [i]DAI J. Densified lignocellulosic fibers, concrete reinforced with such fibers, and...; Published online January 23, 2025. Accessed November 24, 2025. https://patents.google.com/patent/WO2025019374A2; [j]Hu L. Engineered structures fabricated from scrap materials, and systems and methods...; Published online June 26, 2025. Accessed November 24, 2025. https://patents.google.com/patent/US20250205925A1; [k]Winterowd JG. Plant materials with improved water stability, and methods for fabrication...; Published online October 24, 2024. Accessed November 24, 2025. https://patents.google.com/patent/WO2024220910A1; [l]Hu L. Strength-enhanced engineered structural materials, and methods for fabrication...; Published online July 2, 2025. Accessed November 24, 2025. https://patents.google.com/patent/EP4577385A1; [m]Bradshaw A. Truncating the distribution of modulus properties in natural populations of...; Published online February 29, 2024. Accessed November 24, 2025. https://patents.google.com/patent/US20240066748A1; [n]DAI J. Vacuum-insulated structures employing plant materials, and methods for...; Published online May 16, 2024. Accessed November 24, 2025. https://patents.google.com/patent/WO2024102179A2

Business Development Resources for the Testing, Prototyping, and Validation Phase

To translate research into innovation, scientists often face the challenge of launching a product without the entrepreneurial knowledge and skills for market success. This is especially true for technologies emerging from academia, where students and professors often lack a background or experience in business. To address this, funding organizations, incubators, and accelerators can help by providing support and training in business development. These resources include networks and connections to consumers, to enable market-driven technology development and validation, while continuing to provide direct funds for further research aimed at designing, building, and testing prototypes.

The U.S. Government supports business development for new technologies through, for example, the NSF Innovation Corps and Convergence Accelerator programs, which assist in the creation and growth of start-ups. NSF Innovation Corps (I-Corps) is a 7-week incubator program that provides funding and entrepreneurial training to academic researchers, including principal investigators and trainees, to translate their research to products. The I-Corps program connects participants to industry mentors, commercial experts, and potential customers (Example 4). By providing valuable resources and connections, these initiatives help researchers understand the market better. For example, a team from

Purdue University interviewed more than 100 potential customers and companies to identify viable markets across multiple applications for their micro aerial vehicles, portable unmanned flying vehicles used for surveillance, agriculture or other applications.[45] Similarly, a team from Pennsylvania State University conducted 101 interviews with prospective customers ranging from the solar industry to medical device manufacturers to assess the market potential for their antireflective coating.[46] These engagements with potential partners and customers enabled teams to evaluate manufacturing and equipment costs, identify target markets, and estimate potential profitability.[45–47] This understanding allowed them to develop prototypes with consumers in mind and overcome commercialization barriers, ultimately streamlining the market entry process for bioinspired products.[48] Since 2016, I-Corps has supported at least six bio-inspired projects.

Example 4. I-Corps Funded Plant-Inspired Anchor. A recent I-Corps-funded project developed a plant-inspired anchor system that can better resist the forces (such as an earthquake) that may pull a building's foundation from the ground, with a 10% lower cost of installation compared to conventional ground anchors.[a-c] The anchor spreads out like plant roots to cover more area so that it can better and more efficiently distribute strain and resist the forces disrupting the structure.[a,d] The program helped the team to engage with possible customers which informed them on potential barriers to commercialization.[c] After participating in I-Corps, the researchers who developed these anchors were granted a U.S. patent in 2025 and developed a start-up, BioBilt Infrastructure Systems LLC.[b,e]

[a]Huntoon JA, Thomas VM, David Frost J. Life Cycle Assessment of Root-Inspired Ground Anchors and Conventional Ground Anchors. Published online March 23, 2023:1-14. doi:10.1061/9780784484661.001; [b]LLC BIS. BioBilt Infrastructure Systems - Root-Inspired Ground Anchors. Accessed November 24, 2025. https://biobiltanchors.com/; [c]Award Details - NSF Award Search. Accessed November 24, 2025. https://www.nsf.gov/awardsearch/show-award/?AWD_ID=2224250&HistoricalAwards=false; [d]Mallett SD, Frost JD, Huntoon JA. Root-Inspired Anchorage Systems for Uplift and Lateral Force Resistance. Published online May 6, 2021:299-307. doi:10.1061/9780784483411.029; [e]Frost JD, HUNTOON JA, MALLETT SD. Ground anchoring apparatus and method. Published online June 17, 2025. Accessed November 24, 2025. https://patents.google.com/patent/US12331477B2/en?inventor=John+A.+HUNTOON

The NSF Convergence Accelerator (CA) program provides funds of up to $5.75 million per project to aid teams in building prototypes, sustainable company models, and long-lasting partnerships.[49] Recognizing how bioinspired design can be a catalyst for new and innovative goods and services, NSF launched the CA bioinspired design track in 2023.[50] The goal of the track is to support leveraging living systems in solutions to "mitigate complex challenges, including infrastructure monitoring and resilience, food production and human health".[50] Because of the investment provided for networking, training, and team-building, CA can provide more guidance in product testing and validation (Example 5). The bioinspired design track has the potential to accelerate the growth and development of multiple bioinspired projects and highlights how government funds can be vital for pioneering high-risk and unconventional strategies to tackle complex issues. For future success, continued Congressional support is crucial for programs like CA and I-Corps that allow federal agencies to approach challenges in start-up growth outside of product development.

Example 5. Convergence Accelerator Funds Solar Panels Inspired by Plant Behavior. The bioinspired design track is currently developing solar panels inspired by the heliotropic behavior of plants, which bend toward sunlight.[a,b] The project is also responding to the limited adoption of solar panels in residential areas due to cost, design quality, and aesthetics.[c] The research team is using kirigami, the Japanese art of cutting, to create intricate, 2D designs that can more easily be applied to complex building surfaces while being more aesthetically pleasing. The CA program has enabled the project team to form partnerships for manufacturing, solar cell research and development, and aesthetic customization. As well, the team was able to interview several potential customers, similar companies, and experts in related markets and products to inform future product design.[a]

[a]Award Details - NSF Award Search. Accessed November 24, 2025. https://www.nsf.gov/awardsearch/show-award/?AWD_ID=2344424&HistoricalAwards=false#0; [b]Vandenbrink JP, Brown RI, Harmer SL, Blackman BK. Turning heads: The biology of solar tracking in sunflower. *Plant Science*. 2014;224:20-26. doi:10.1016/j.plantsci.2014.04.006; [c]Limited TC. YES Blog. YES Energy Solutions. November 6, 2025. Accessed November 24, 2025. https://www.yesenergysolutions.co.uk/tools-resources/yes-blog/

The Impact of Private Funding on Bioinspired Start-Up Development

Due to the uncertainty of success and the inherent risks in supporting product development at the earliest stages, government programs are the primary source of crucial funding support for start-ups to survive the valley of death. Nevertheless, some non-dilutive, private funding options are available to supplement federal investment and advance early product development. Private funding incubator programs, which aid start-up creation through product validation

and business training, have been highly consequential as catalysts for the continuation of bioinspired innovation in the U.S.

Notably, there are a few non-profits that provide the necessary resources to support bioinspired products during the testing and validation phase so that they can be derisked. One such non-profit is the Bozeman, Montana-based Biomimicry Institute, which supports bioinspired design.[51] The Biomimicry Institute's Ray of Hope Accelerator provides $15,000 in non-dilutive funds for product ideation and development, and additional business development services worth over $50,000 per project, such as tailored coaching, investor introductions, and training materials to early-stage start-ups (Example 6).[52,53] To date, the Ray of Hope Accelerator has supported the launch of over 30 U.S. start-ups that apply biomimicry in their product design while advancing sustainability goals, such as lowering energy use and improving infrastructure.[54] However, the Biomimicry Institute supports only a limited number of start-ups, with minimal funding for direct product development and without a focus on U.S. investment.[53] With these limitations, subsequent funding, including government funding, after the end of the Ray of Hope Accelerator remains paramount for bioinspired start-up products to reach eventual market entry. The success of U.S ventures comes from both government and private sectors, highlighting the importance of continued Congressional support to extend funding reach.

Example 6. From Pitcher Plants to Bioinspired Non-stick Coating. The Ray of Hope Accelerator supported spotLESS Materials Inc., a start-up founded in State College, Pennsylvania. The U.S. venture developed a non-stick coating inspired by pitcher plants. Pitcher plants have a specialized surface at their rims which makes the rim particularly slippery (or "wettable"), resulting in insects and other prey that land on the rim to slip and fall in.[a-c] Drawing on this biological principle, the start-up created a spray coating for household surfaces to keep them clean, which repels liquids and resists bacteria and mineral deposits.[d,e] Around the same time as receiving support from the Ray of Hope Accelerator, spotLESS Materials also received two SBIR awards from NSF,[f,g] enabling further derisking of the product and leading to its acquisition.

[a]Bohn HF, Federle W. Insect aquaplaning: Nepenthes pitcher plants capture prey with the peristome, a fully wettable water-lubricated anisotropic surface. *Proceedings of the National Academy of Sciences*. 2004;101(39):14138-14143. doi:10.1073/pnas.0405885101; [b]Bauer U, Bohn HF, Federle W. Harmless nectar source or deadly trap: Nepenthes pitchers are activated by rain, condensation and nectar. *Proceedings of the Royal Society B: Biological Sciences*. 2007;275(1632):259-265. doi:10.1098/rspb.2007.1402; [c]Bauer U, Federle W. The insect-trapping rim of Nepenthes pitchers: surface structure and function. *Plant Signaling & Behavior*. 2009;4(11):1019-1023. doi:10.4161/psb.4.11.9664; [d]Surface Coating for Glass and Ceramic Inspired by the Pitcher Plant — Innovation — AskNature. Accessed November 24, 2025. https://asknature.org/innovation/surface-coating-for-glass-and-ceramic-inspired-by-the-pitcher-plant/; [e]spotLESS Materials. spotLESS Materials. Accessed November 24, 2025. https://www.industry.spotlessmaterials.com; [f]Award | SBIR. Accessed November 24, 2025. https://www.sbir.gov/awards/171565; [g]Award | SBIR. Accessed November 24, 2025. https://www.sbir.gov/awards/178170

The Wyss Institute at Harvard University has similarly aided start-ups in covering the costs of development, scale-up, commercialization, and market entry for bioinspired products through the support of its collaborators, investors, and industry partners.[55,56] With a specific focus on bioinspired product development and commercialization, the institute provides assistance ranging from direct mentorship from investors, entrepreneurs, and scientists, to providing direct connections to venture capital, philanthropies, previous collaborators, and funding from Harvard.[57] These resources work to bridge gaps in knowledge, investment, and other resources needed to create bioinspired goods and services. For example, Northpond Labs Alliance and Collaborative Fund Alliance have provided $12 million and $15 million, respectively, to the Wyss Institute to develop laboratories for research and innovation.[58,59] Furthermore, the Wyss Institute's Diagnostics Accelerator and Immuno-Engineering to Improve Immunotherapy Center collaborate with local hospitals and cancer centers to further bioinspired research that can lead to better testing and treatments.[60,61] From 2009 to 2025, the Wyss Institute obtained more than $2.7 billion for bioinspired start-up venture funding.[57] With its funding support and collaborations, the Wyss Institute has enabled 71 bioinspired start-ups, over 1900 new jobs, 3180 publications, 4702 filed patents, 1759 issued patents, and 153 licenses in 16 years.[57] These accomplishments underscore the impact of private funding in advancing the Wyss Institute's objective of leveraging bioinspired design to achieve market entry.

The success of projects within the Wyss Institute have been possible due to its network and collaborations, highlighting the value of partnerships between research institutions, academia, industry, and venture capital (Example 7). However, as a non-profit within Harvard University, the institution mainly works to support bioinspired start-ups affiliated with Harvard,

within the Boston/Cambridge ecosystem, or those that have established specific partnerships with the Institute.[56,62] U.S. government funding, meanwhile, can support start-ups distributed across the U.S., without such affiliation limitations (and including those at Wyss who have had success in obtaining SBIR/STTR grants).[32,34,63,64]

Example 7. 3D Printed Grafts Mimic Ear Drum Structure for Nonsurgical Treatment. Researchers, supported by the Wyss Institute, developed a biodegradable, 3D printed structure that replicates the shape and pattern of an eardrum.[a,b] This can be inserted into a perforated eardrum so that it can heal properly without requiring surgery. At the Wyss Institute, the research team secured lab space and grew their team to broaden expertise in science and business. Afterwards, the new Beacon Bio start-up joined an innovation lab which provided resources, training, and start-up connections. Through the innovation lab program, the team won the 2021 Harvard President's Innovation Challenge, a $25,000 prize.[c] With continued success during their tenure at the Wyss Institute, they were connected with Desktop Health, a company that specializes in 3D printing, which later acquired the start-up.[c] Altogether, support from the Wyss Institute has assisted in the development of Beacon Bio's 3D printed eardrum graft and multiple other bioinspired products with societal applications. This aid was possible because of the Institute's broad connections across technology development and the private funding landscape.

[a]PhonoGraft: 3D Printed Tympanic Membrane Graft. Wyss Institute. June 8, 2021. Accessed December 23, 2025. https://wyss.harvard.edu/technology/phonograft-3d-printed-tympanic-membrane-graft/; [b]Kozin ED, Black NL, Cheng JT, et al. Design, fabrication, and in vitro testing of novel three-dimensionally printed tympanic membrane grafts. *Hear Res* . 2016;340:191-203. doi:10.1016/j.heares.2016.03.005; [c]Harvard's eardrum-restoring PhonoGraft enters commercial development. Wyss Institute. August 19, 2021. Accessed November 24, 2025. https://wyss.harvard.edu/news/harvards-eardrum-restoring-phonograft-enters-commercial-development/

It is important for the federal government to continue supporting bioinspired design especially at the research and early start-up development phase. With the combined support of public and private funding, bioinspired start-ups have more opportunities for successful development and market entry. Ultimately, the current Congressional funding model is essential because it enables federal agencies to address gaps in support until private funding sources become available. Therefore, continued appropriations to these agencies are necessary to sustain these vital programs.

Looking Forward

As society faces new challenges in health, environment, infrastructure, energy, and more, bioinspiration has been a pathway to generate novel and unorthodox ideas. However, the economic and societal gains achieved from bioinspiration are impossible without the foundational biological research necessary to catalyze these solutions. From the translation of foundational biological research to bioinspired design, start-ups have developed advancements such as biodegradable 3D prints for eardrum reconstruction, sustainable building materials made from corrugated wood, and anti-fouling materials inspired by shark skin. Through products like these, bioinspired design has enabled fundamental research to influence many industries within and beyond biology. Additionally, the advantages of bioinspiration extend past product applications to industry and job growth. The potential impact of bioinspired design on economic value, human health and well-being, sustainability, and innovation underscores the critical need for sustained congressional support, from fundamental research to eventual commercialization.

From government and non-profit, to venture capital, funders within the U.S. innovation ecosystem must maintain support of bioinspiration across the valley of death. While support beyond government funding, such as venture capital and other private sector investment, is necessary to achieve market-scale development, government seed grants can increase the chances of future investment. After receiving an NSF seed fund award, companies were five times more likely to secure outside investment, even though they had less than one-seventh the non-governmental funding of companies that were not selected prior to the award.[65] After the award, the amount of funding for both groups (NSF-funded and not) are found to be statistically similar. Also, companies launched with NSF seed funds were almost eight times as likely to file for a patent and had almost five times as many patents awarded.[65] Therefore, initial seed funding from the U.S. government is crucial to supporting bioinspired start-ups, because early investment supports these companies not only in their testing, validation, and development phases, but also in securing future private funding for scale-up and commercialization. Once these products have been derisked, venture capital and other private funding must be the leader in aiding these start-ups in pursuing market entry.

Given the potential value of bioinspired products and solutions to the U.S. and the world, sustained congressional support for foundational biological research is crucial. Congress should maintain or increase appropriations to federal agencies, such as NSF, to fund programs and initiatives that assist researchers and start-ups in navigating the valley of death. Additionally, more awareness of the current levels and types of funding support for bioinspiration and how that support is being distributed would allow U.S. federal funding agencies and institutions to coordinate where their funding could most effectively impact the innovation landscape. It is also important for funders to determine how their funding impacts the innovation landscape through start-up creation and progression to new products entering the market. Tracking and publishing the successes from funding research and start-ups will help to validate the continuation of these programs, especially to Congress, while also attracting more individuals looking to develop their research into products. With continued or even increased government funding for early start-up development and transparency of the funding landscape and start-up successes, the U.S. can maintain global dominance in science and technology innovation. Otherwise, the U.S. may miss significant opportunities to maintain its economic lead and to benefit the lives of its citizens through groundbreaking products derived from our most creative ideas and unconventional sources. Therefore, Congress must not waver in their support of bioinspiration at all stages of the research and innovation landscape.

Supplemental Information

Supplemental information available at: SBIRSearchSheet

The terms biologically inspired, bioinspiration, bio inspiration, bioinspired, bio inspired, nature inspired, bionic, biomimetic, and biomimicry were searched in the SBIR/STTR grant search engine (https://www.sbir.gov/awards) to identify projects referencing bioinspiration. The resulting datasets were downloaded as CSV files and copied into the corresponding sheets of this .xlsx file. Duplicate results were identified using Microsoft Excel's XMATCH function in the sheet 'MATCH' to calculate the final number of unique grants referencing bioinspiration. If there is a duplicate then, the cell will report the value of the row that is duplicated from the corresponding excel sheet, otherwise the cell value will be "#N/A". Hyphenated terms returned mostly unrelated results and were therefore excluded from the query.

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