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Perspective

A field biology guide for the curious physicist

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ACCESSIBLE OVERVIEW Over the years, an increasing number of physicists and engineers have drawn inspiration from biology. Often, the best source of inspiration from biology is found in natural environments. However, conducting field research can present a daunting challenge for scientists who have never ventured beyond their labs or computer screens. This perspective offers a practical guide for interdisciplinary, curiosity-driven field research, based on experiences from designing the *in situ* Jungle Biomechanics Lab, a field course that teaches interdisciplinary research in the Peruvian Amazon Rainforest.

This perspective outlines seven essential steps for planning and executing field research that is scientifically robust, logistically sound, and ethically responsible. These steps include finding the right location, maintaining curiosity, logistical planning to ensure safety, fostering a supportive culture, interdisciplinary collaboration, giving back to local communities, and promoting iterative improvement. Collaborating with naturalists, especially locals, is crucial for deepening biological understanding. The *in situ* approach to field research emphasizes engagement with local communities and fosters meaningful, reciprocal relationships.

Physicists offer valuable perspectives and tools for biological research. Similarly, biologists and naturalists can provide fresh insights into physics and engineering, particularly in areas that involve bioinspired design. Interdisciplinary training that emphasizes collaboration and communication can create a stronger foundation for all sciences, enabling every field to tap into new creativity and a broader scope.

SUMMARY

Fieldwork is an essential component for an expanding umbrella of research on the physics of living systems, where observing organisms in nature is a critical component of discovery. However, conducting field research can be a barrier for scientists, in particular physicists, who do not have experience working with organisms under challenging field conditions. Here, we propose seven critical steps for organizing and executing interdisciplinary, curiosity-driven field research. Our recommendations are drawn from insights gained from the *in situ* Jungle Biomechanics Lab, a field research course that helps early-career scientists from both physical and life sciences gain experience in both organizing and conducting interdisciplinary field research in the Amazon Rainforest. We emphasize a curiosity-driven approach toward the scientific inquiry of living systems, which we believe is crucial for discovery while working with wild organisms under unpredictable field conditions. We further provide guidance on teamwork when conducting fieldwork, including creating an inclusive environment and advocating for codes of conduct and team structures that aid in conflict resolution. Finally, we outline an *in situ* approach to fieldwork

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that requires engagement with the environment, scientific community, and local people where field sites exist.

INTRODUCTION

Whether it is the superpropulsion of planthopper pee droplets,[1] information propagation in swarms of fireflies,[2] or a caterpillar's ability to detect predators' electric fields,[3] many organisms operate at the limits of what is physically possible. This has led to an increased interest among physical scientists and engineers to use their training in physics, mechanics, and instrumentation to understand the physics of living systems. However, those organisms are not always amenable in a controlled laboratory environment, may only perform extreme behaviors in the wild, and often exist in biodiversity hotspots in remote places; thus, scientists often need to meet organisms where they naturally live.

Studying organisms in the field presents an array of challenges that can be daunting not just from a scientific perspective but also from logistical and conceptual standpoints. Many questions may arise, such as what are the expected costs of fieldwork? What happens if one cannot find the organism of interest in the study? What challenges does fieldwork present in team leadership? How do you find a research question to begin with? Here, we aim to provide a field guide for scientists who have not had the opportunity to perform field research with wild living organisms in their natural settings. This guide is based on lessons learned from the Jungle Biomechanics Lab (JBL), an NSF-IRES program that takes scientists with expertise ranging from fluid mechanics to theoretical physics into the Peruvian Amazon (Figure 1). It draws on insights from scientists who have been doing fieldwork with living organisms for more than a decade but, critically, also includes the perspective of physical scientists doing biological fieldwork for the first time. We approach field research from a curiosity-driven science perspective, which is amenable to the uncertainty that field research often presents. Finally, we advocate for an *in situ* approach to fieldwork, an approach that we think of as antithetical to parachute science and requires engagement with the greater community where the field sites exist.

Finding a field site

A field site may be anywhere: a literal field, a suburban backyard, or even the sewers of New York City.[4] Anywhere organisms have adapted to survive, there is likely unexplored biophysics to discover. However, the more challenging the environment, the more difficult it might be for a scientist to gain access and make observations. Identifying the perfect place to study a system in the field requires a careful balance of funding acquisition and field site choices that have adequate infrastructure to support the relevant scientific inquiry. Thus, we suggest starting with a budget, which can determine the appropriate choice for the field site location.

With a budget in mind, it is time to decide *where* to go. Finding a place to do fieldwork may be as simple as using Google Maps to look for freshwater ponds, in the case where one is setting out to study dogfighting dragonflies. For questions that can only be answered with organisms further from reach, biological field stations can be a critical resource for conducting field-based research with living systems. Biological field stations offer infrastructure that might be necessary for the execution of prolonged and technically challenging research. The resources at field stations are dependent on how established or remote the station is, and the fees are often correlated with the available benefits. For example, some stations may have full wet-lab facilities and dormitories, whereas others may have limited electrical access. There are thousands of biological field stations globally, and databases exist to help locate a suitable research location for conducting biological field research.[5]

So, what can you do if field research is inaccessible to you? First, many field stations offer opportunities for research assistants, where room and board are often covered in return for assisting with ongoing research. Many universities and institutions offer travel grants and scholarships specifically for international field research. Check with your institution's financial aid office or research department for available funding opportunities. Organizations like the Society for Integrative and Comparative Biology (SICB), the Company of Biologists, and the Ecological Society of America (ESA) provide grants and fellowships to students and early-career researchers to engage in international research. Faculty can incorporate field research in their grants. The genesis of the JBL was part of the Broader Impacts of S. B.'s NSF CAREER proposal,[6] which later evolved into a full NSF grant through the IRES program.[7] Foundations such as National Geographic, Moore, and Fulbright also offer grant opportunities for education-related activities.

Finding research questions in organismal biophysics: A curiosity-driven perspective

The modern academic science workflow pressures scientists to publish and to publish quickly. To a behavioral ecologist, identifying lines of scientific research can often feel similar to the "explore/exploit" problems that animals face. Just like an organism needs to balance its time between using the resources readily available (exploit) and looking for new resources for when current supplies dry up (explore), scientists must also balance time between collecting data for lines of questions that produce publishable results and finding new directions of research. For many career scientists, it can then be difficult to dedicate time purely toward the explore process. Developing new lines of research in organismal biophysics, however, demands slowing down and taking the time to simply observe.

An approach we advocate is to go into the explore phase with a curiosity-forward strategy. A curiosity-driven approach emphasizes observation as the motive force behind discovery. Many significant findings in organismal biophysics begin with observations of organisms often by accident, for example, squirrel acrobatics,[8] dog slurping,[9] springtail aerodynamics,[10] cellular origami,[11] cat grooming,[12] insect excretion,[13] caterpillar electrosensation,[3] planthopper gears,[14] snapping shrimp,[15] firefly flashes,[2] elephant trunks,[16] and leaping eels.[17] We see the curiosity-driven approach to exploration in action at the JBL, as the

Figure 1. Recommended steps for building an effective, collaborative, and safe field research program

(1) Find a field site for curiosity-driven research. (2) Identify new lines of research with emphasis on curiosity and observation. (3) Plan the trip meticulously and with a safety mindset. (4) Establish a culture of respect for all participants. (5) Collaborate with other scientists across disciplines. (6) Give back to local communities. (7) Iterate and improve the program based on feedback.

program is a natural experiment that asks what happens when we bring early-career researchers from fields ranging from theoretical physics to microbial ecology into an unfamiliar field site with high levels of biodiversity. The course is designed with structured spontaneity at its core, giving early-career researchers unfettered room to spend time solely in an explore phase. We believe that this encourages researchers to stop, think, and observe and, without exception, quickly find an unresolved research question, such as the flight control of cicadas who have lost their entire abdomen due to a *Massaspora* infection, or where ant lion larvae choose to build their sandy pits. A curiosity-driven approach requires open-mindedness to be flexible and not take seemingly simple behaviors of organisms for granted. Curiosity, however, is necessary to practice. As George M. Whitesides[18] aptly observed,

> Because following curiosity can seem effortless, it is easy to assume it does not need to be learned, practiced, or encouraged, that it is not important, and that it will somehow take care of itself. But, as with many activities that are competing for time and attention in a utilitarian world, curiosity can atrophy from neglect. It can certainly be unfocused, and lead to nothing (or at least nothing immediately useful), but using it as the starting point for careful observation of nature and society is a nontrivial skill, and a starting point for new intellectual endeavors and adventures. It is one essential contributor to creativity in science, and a start in forcing new ideas into inflexible professional orthodoxies.

Preparing for fieldwork: Safety before science

Preparation for any fieldwork can vary vastly depending on the location of the field site, the study organisms, the experience level of the research team, and the equipment needed to answer any scientific questions. Therefore, it is difficult to offer all-encompassing guidance on exactly how to prepare for field research. Here, we offer a simple frame of mind that was critical in our own preparation: placing safety and transportation as first-order priorities.

Safety and transportation logistics for fieldwork should always begin with a detailed risk management plan. A risk management plan should include an outline of basic expectations for safe conduct and operating procedures for an emergency. We have included a field safety guide template used for JBL (Note S1). Critically, while preparing any safety plan for field research, you should be cognizant that safety risks can vary among individuals from different backgrounds and identities.[19] In addition to a safety plan while in the field, a strong fieldwork plan lays out detailed logistics regarding travel. Local fieldwork may only need a carpool sign-up sheet to ensure equitable access among participants. For fieldwork farther away than a short drive, specific details around travel logistics can get lost in early preparation steps, so we recommend having an explicit travel plan that outlines how each participant will get to the field site, which elements each person is responsible for, and a backup plan in case something should impede travel, while staying within the estimated budget. A strategy that builds a detailed logistical foundation will facilitate more technical and specialized research. It is also imperative to understand local laws regarding sample collection and for research activities. Different countries may have specific laws about exporting samples if you intend to return with preserved specimens.

We would like to emphasize that many great discoveries in organismal biophysics required only a keen eye and no specialized equipment at all. Much of our own research is implemented with phone cameras and some extra lighting. As a reference, we include example gear lists for our own fieldwork (Note S2). We believe that a successful round of fieldwork is one that gets all participants on site and back safely, and a tremendously successful field excursion is where participants return energized with ideas, data, and often a new research direction.

Establishing a culture of mutual respect

Collecting data in 40°C and high humidity for multiple days in a row is hard. It can be even harder if the internet connection is limited, you have forgotten a crucial piece of equipment for your experiments, or you have not been able to find any of the species of interest in the field. In such moments, miscommunication may occur, leading to interpersonal conflict. Disagreements are not signs of dysfunction, but how disagreements are handled is crucial for fostering a creative research environment. A code of conduct and a clear leadership structure proactively outline expectations for participants well before the fieldwork begins. This provides a clear throughline for conflict resolution and tackling most interpersonal issues before they arise.

A code of conduct is a document that explicitly states the rules and values of a team or organization and includes clear consequences for violating such rules. We recommend using the field code of conduct developed by the Association of Polar Early Career Scientists (APECS) to establish expectations among researchers.[20] The APECS code of conduct has clear definitions for what constitutes harassment and a zero-tolerance policy for harassment, as well as an internal leadership structure that provides both on-site and off-site independent contacts to report and initiate actionable consequences for inappropriate behavior. All participants should read and sign the code of conduct before beginning fieldwork. The values outlined in the document include, but are not limited to, not putting oneself or others in dangerous situations, respecting personal boundaries, and showing respect for the land, its organisms, and the broader community. Incorporating principles of respect and inclusion is imperative to empower the next generation of field scientists.

Collaborate across disciplines and especially with naturalists

Field stations are crossroads for wide-ranging corners of the scientific community from all career stages and disciplines. The same field site may simultaneously be a temporary home to industrial engineers, ornithologists, and disease ecologists across career stages. The confluence of expertise at field stations is an invaluable opportunity for unexpected collaboration. Oftentimes, executing complex field experiments requires input from expertise outside of one's own knowledge domain or simply a few more sets of hands to perform experiments. A key consideration when planning field research is to work with scientists from a broad range of expertise. For instance, a physicist interested in the locomotion of tiny organisms may benefit from the expertise of a cell biologist who has spent a career imaging organisms under a microscope. Researchers with expertise in mechatronics may be indispensable for the *ad hoc* fabrication of a force transducer from spare strain gauges, and a theoretical physicist may have an otherwise overlooked perspective on modeling the collective behavior of gregarious caterpillars. One additional collaboration we especially implore for the physicist beginning field biology to partake in is that with naturalists.

Naturalists are scientists who have expertise gained from years of careful observation and insights into organisms in their natural habitats, such as when/where can I even find my study organism? Naturalists have a wealth of knowledge of organisms that is often difficult to extract from the literature alone. This knowledge has proven indispensable as the starting point for a physics-based inquiry of an organism's behavior. For example, a naturalist might note that a family of butterflies, the metalmarks (*Riodinidae*), has a habit of landing upside down on the underside of leaves—at first, a seemingly simple and innocuous observation. However, for an expert in flight control, this can be understood as an inordinately complex task and has the potential to generate an entire line of research questions to dissect the control mechanisms of upside-down takeoff and landing. The knowledge of naturalists is indispensable for identifying new lines of research questions that are suitable for the quantitative and experimental skills of physicists and engineers. Collaboration with naturalists should be a key component in any plans to do organismal fieldwork, especially at an unfamiliar location.

The *in situ* approach to field biology

In addition to finding field sites, organisms, and research questions, we especially want to emphasize what we describe as the *in situ* mindset for fieldwork. Here, we use the term *in situ* to mean engaging both physically and mentally with the environment where field research takes place. We intend for the *in situ* approach to be an antithesis to parachute science, a practice where researchers from high-resource institutions drop in, extract samples, and leave without acknowledging or contributing toward local knowledge.[21] To us, the *in situ* approach requires presence and engagement at three interlocking levels: the environment, the scientific community, and also the greater community where a field site exists.

In situ engagement with the environment signifies understanding field research through the lens of an environmental identity. An environmental identity is a term used to refer to how we see ourselves in relation to the natural world.[22] For example, a scientist's environmental identity may relate to the rainforest as a biodiversity hotspot with a new parasitic wasp waiting to be discovered. For a subsistence farmer in the same region, the relationship between the rainforest and the person may be about day-to-day livelihood. Fieldwork can and should be understood in the social context of the environments in which it occurs. *In situ* within the local scientific community reflects an understanding that, as scientists, we have a responsibility as mentors and colleagues. Scientists at all levels from localities where fieldwork occurs are invaluable collaborators and, wherever possible, should be included. For our own field research, this includes collaborations with scientists from local universities, especially including undergraduates as active participants in research projects. Finally, *in situ* at the community level reflects a commitment to being active participants not just in science but also in the local communities where the science takes place. Community involvement is an opportunity, a responsibility, and a privilege when conducting field research. This may be performing outreach events showcasing research to grade-school children, inclusion of local teachers and farmers, or even establishing community scientific resources at field sites. No single stratum of the three layers of an *in situ* approach exists alone, and each is indispensable for conducting field research.

Iterating improvements from quantitative and qualitative information

Science is by nature an iterative process, and how we conduct and lead our scientific research is also subject to continuous fine-tuning. Both quantitative and qualitative data from field researchers are crucial toward improving and iterating upon any fieldwork. Getting data from participants before and after any complex field research via tools such as anonymous surveys is a key step. This way, you are more likely to have meaningful data that will allow you to improve any element of field research that did not work as intended and can be immediately addressed. We have provided an example survey that we have used in the past (see Note S3). Qualitative data require making measurable what is not so. Part of our philosophy was to give equal footing to all field researchers, regardless of whether they were postdocs or undergraduates. Within a culture of mutual respect, researchers, whether postdoc or undergraduate, can freely express and suggest improvements that will lead to the completion of a project. Both elements are crucial for establishing a long-term, successful research program that includes challenging fieldwork components.

Concluding remarks

In an interdisciplinary scientific community, organismal biology is enriched from the perspectives of physicists and engineers whose expertise in quantification, instrumentation, and computational frameworks is primed to answer fundamental questions about how organisms work. We hope that our guided steps in the design of fieldwork programs can help a larger number of scientists from disparate fields to engage in efforts related to biological systems that require research where organisms have evolved to thrive. Field research is an integral part of organismal biology research. As more disciplines seek to draw inspiration from biological systems, it is critical that those fields engage the ecological context of their biological study systems. Starting a field biology project may seem overwhelming to those who have not had the opportunity, but we argue that it is worth the trouble. We see opportunity in embracing more physical scientists into the naturalist traditions of the past few centuries and envision expanding opportunities in the physics of living systems.

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DECLARATION OF INTERESTS

The authors declare no competing interests.

SUPPLEMENTAL INFORMATION

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REFERENCES

1. Challita, E.J., Sehgal, P., Krugner, R., Bhamla, M.S., and Bhamla M, S. (2023). Droplet superpropulsion in an energetically constrained insect. Nat. Commun. *14*, 860.
2. Sarfati, R., Hayes, J.C., and Peleg, O. (2021). Self-organization in natural swarms of photinus carolinus synchronous fireflies. Sci. Adv. *7*, eabg9259.
3. England, S.J., and Robert, D. (2024). Prey can detect predators via electroreception in air. Proc. Natl. Acad. Sci. USA *121*, e2322674121.
4. Guo, X., Himsworth, C.G., Lee, M.J., and Byers, K.A. (2023). A systematic review of rat ecology in urban sewer systems. Urban Ecosyst. *26*, 223–232.
5. Tydecks, L., Bremerich, V., Jentschke, I., Likens, G.E., and Tockner, K. (2016). Biological field stations: A global infrastructure for research, education, and public engagement. Bioscience *66*, 164–171.
6. (2020). NSF award search: Award # 1941933 - CAREER: Fast, furious and fantastic beasts: Integrative principles, biomechanics and physical limits of impulsive motion in ultrafast organisms. https://www.nsf.gov/awardsearch/showAward?AWD_ID=1941933&HistoricalAwards=false..URL.
7. (2023). NSF award search. Award # 2246236 - IRES track1: In-situ jungle biomechanics laboratory (JBL) research experience in the amazon rainforest. https://www.nsf.gov/awardsearch/showAward?AWD_ID=2246236&HistoricalAwards=false.
8. Hunt, N.H., Jinn, J., Jacobs, L.F., and Full, R.J. (2021). Acrobatic squirrels learn to leap and land on tree branches without falling. Science *373*, 697–700.
9. Gart, S., Socha, J.J., Vlachos, P.P., and Jung, S. (2015). Dogs lap using acceleration-driven open pumping. Proc. Natl. Acad. Sci. USA *112*, 15798–15802.
10. Ortega-Jimenez, V.M., Challita, E.J., Kim, B., Ko, H., Gwon, M., Koh, J.S., and Bhamla, M.S. (2022). Directional takeoff, aerial righting, and adhesion landing of semiaquatic springtails. Proc. Natl. Acad. Sci. USA *119*, e2211283119.
11. Flaum, E., and Prakash, M. (2024). Curved crease origami and topological singularities enable hyperextensibility of l. olor. Science *384*, eadk5511.
12. Noel, A.C., and Hu, D.L. (2018). Cats use hollow papillae to wick saliva into fur. Proc. Natl. Acad. Sci. USA *115*, 12377–12382.
13. Challita, E.J., and Bhamla, M.S. (2024). Unifying fluidic excretion across life from cicadas to elephants. Proc. Natl. Acad. Sci. USA *121*, e2317878121.
14. Burrows, M., and Sutton, G. (2013). Interacting gears synchronize propulsive leg movements in a jumping insect. Science (Wash. D C) *341*, 1254–1256.
15. Patek, S.N., Korff, W.L., and Caldwell, R.L. (2004). Deadly strike mechanism of a mantis shrimp. Nature *428*, 819–820.
16. Schulz, A.K., Boyle, M., Boyle, C., Sordilla, S., Rincon, C., Hooper, S., Aubuchon, C., Reidenberg, J.S., Higgins, C., and Hu, D.L. (2022). Skin wrinkles and folds enable asymmetric stretch in the elephant trunk. Proc. Natl. Acad. Sci. USA *119*, e2122563119.
17. Catania, K.C. (2016). Leaping eels electrify threats, supporting Humboldt's account of a battle with horses. Proc. Natl. Acad. Sci. USA *113*, 6979–6984.
18. Whitesides, G.M. (2018). Curiosity and science. Angew. Chem. *57*, 4126–4129. https://doi.org/10.1002/anie.201800684.

19. Demery, A.J.C., and Pipkin, M.A. (2021). Safe fieldwork strategies for at-risk individuals, their supervisors and institutions. Nat. Ecol. Evol. *5*, 5–9.

20. Association of Polar Early Career Scientists (APECS) (n.d.). Field Code of Conduct. https://www.apecs.is/career-resources/diversity-equity-inclusion/field-code-of-conduct.html. Accessed: 2025-06-23.

21. Odeny, B., and Bosurgi, R. (2022). Time to end parachute science. PLoS Med. *19*, e1004099.

22. Clayton, S., and Opotow, S. (2003). Identity and the Natural Environment: The Psychological Significance of Nature (MIT Press).