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Perspectives

Beauty in biology: An empirical assessment

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'Beauty' is not a word typically associated with science. Nevertheless, numerous scientists in recent years have expounded on the role of beauty in science. These writings tend to be largely concentrated in theoretical physics. But what role does beauty play in the biological sciences? To answer this question, this article analyzes data from a large international study of scientists working at PhD-granting institutions in the US, UK, Italy, and India. Drawing on nationally representative surveys (N=1381) and in-depth interviews (N=104) with biologists in the sample, the article summarizes what 'beauty' means to biologists, where they encounter beauty in the practice of science, where in the scientific process they see aesthetic factors as relevant, and what they see as the consequences of encountering beauty in scientific work. The results show that most biologists in the four countries encounter beauty in the phenomena they study, and associate beauty primarily with the inner logic of systems. Most also find beauty relevant to presenting and analyzing results, and see it as a motivation for teaching as well as for pursuing scientific careers. While most biologists think it is important for scientists to encounter beauty in their work, they do not see it as always necessary or achievable.

Keywords. Aesthetics; beauty; interviews; survey

1. Introduction

While 'beauty' is not typically a word associated with science in popular parlance, numerous scientists in recent years have expounded on the role of beauty in science. These writings tend to be largely concentrated in physics, with a particular focus on the role of beauty in scientific theories (e.g., Chandrasekhar 1987; Livio 2000; Zee 2015; Wilczek 2016; Hossenfelder 2018). Discussions on the role of beauty in biology tend to concentrate on either the beauty of the natural world (e.g., Weiss 2021), biological explanations for beauty and sexual preferences (Grammer *et al*. 2003; Fink and Neave 2005; Johnston 2006; Prum 2012) or the biological bases for aesthetic practices and preferences in humans and other animals (Chaplin 2005; Conway and Rehding 2013; Prum 2013; Chatterjee and Vartanian 2014; Zeki *et al*. 2018; Nusslein-Volhard 2019; Skov and Nadal 2021). Philosophers of science have also discussed the relevance of aesthetic criteria in experiments in biology – particularly, those that are considered 'beautiful' experiments, such as the Michelson–Morley experiment (Ivanova 2021). But with few exceptions (e.g., Dawkins 1998; Gilbert 2017; MacArthur 2021), we know little about the role of aesthetic experiences in the practice of science among biologists.

Existing literature also suggests that physicists and biologists have different conceptions of beauty (MacArthur 2021). While both appreciate the beauty of the natural world, physicists tend to see beauty in the simplicity and elegance of abstract laws formulated in mathematical terms (Livio 2000), whereas biologists tend to experience beauty in the abundance and diversity of the natural world and the 'intricacy, interconnection, and complexity' of nature and life (MacArthur 2021). In physics, there is also a tendency to treat beauty as a heuristic – simple and elegant equations are considered more likely to be true than those that are not (McAllister 1996), and such reliance on aesthetic criteria is seen by some as a source of cognitive bias in physics (Hossenfelder 2018).

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Biologists, however, may be unlikely to use aesthetic factors in this heuristic manner. Because of the complexity of life, biologists may care more about particulars and contexts than physicists do. As MacArthur (2021) notes, bone cells and brain cells may have similar genetic material but are different in their function and interaction with their extracellular environments. These intricacies can only be understood through meticulous study and cannot be reduced to explanations at lower (e.g., atomic) levels of reality. For this reason, reductionism, which is a key aesthetic principle in physics (Livio 2000), may not apply to biology. Well-defined taxonomies are needed to categorize and explain life's enormous complexity and diversity. In applied biological sciences especially, such as drug development, particular details such as the drug's modes of action are more crucial to understand than general principles (MacArthur 2021). Since biological reality is inherently complex, good explanations rely on specific details within specific contexts to provide depth and richness.

A deeper understanding of the distinctive aesthetic aspects of biology may allow for better communication and collaboration between biological sciences and other disciplines. Understanding what scientists in a particular discipline find aesthetically pleasing in their work is also important because it points to a key source of motivation, as research on science education suggests (e.g., Jacobson and Wickman 2008; Pugh and Girod 2007; Wickman *et al*. 2022; Ferguson *et al*. 2022). Research also suggests that frequent aesthetic experiences in scientific work are associated with higher levels of psychological well-being among scientists (Jacobi *et al*. 2022). As MacArthur (2021) argues, 'What we consider beautiful informs the questions we ask and the answers we consider plausible'. For these reasons, it is important to shine a light especially on the taken-for-granted aesthetic criteria that may be shaping research in the biological sciences.

In what follows, we summarize the results from an international study of scientists, and we focus in particular on the aesthetic experiences of scientists in the biological sciences. We examine what 'beauty' means to biologists, where they encounter beauty in their scientific work, where in the practice of science they see aesthetic criteria as relevant, what they see as the consequences of encountering beauty in their work, and their overall evaluations of the role of aesthetics in science. Our goal here is simply to summarize our key descriptive findings on these questions as an important starting point for discussion and further analysis.

2. Data and methods

Data for this article come from an international study of scientists in physics and biology departments at PhD-granting institutions and research institutes in four countries: India, Italy, the United Kingdom, and the United States of America.

We examined physics and biology as two core scientific disciplines that are known to have important aesthetic differences (MacArthur 2021). The four countries selected allowed us to examine the relationship between aesthetics and science in distinct societal contexts. The four countries also differ in terms of research infrastructure in terms of the percentage of GDP spent on research and development (US: 2.83%, UK: 1.7%, Italy: 1.39%, and India: 0.65%; The World Bank 2021). The four countries also have distinctive cultural histories which likely shape aesthetic traditions and formation, which in turn might affect the aesthetic experiences of scientists in those countries. Finally, the four countries were chosen because they garnered the highest survey response rates in a previous large-scale international survey of scientists (Ecklund *et al*. 2019); as a result, we had research collaborators and institutional support in place to facilitate data collection in these countries, ensuring a higher probability of success in these countries.

We conducted nationally representative surveys of the target population in each country and achieved a completion rate of 15% (N=3442). Data collection occurred between May and October 2021. This study received human subjects' research approval from the Institutional Review Boards of The Catholic University of America and the University of Notre Dame. Informed consent was obtained from all participants. A detailed methodological report and other study materials are available at *https://workandwellbeingstudy.com/wp-content/uploads/2022/05/WWB_Methodology.pdf*.

To minimize selection bias in our sample, we branded our project the 'Work and Well-Being in Science' study. We did so particularly to avoid biasing the survey towards participants who cared about aesthetics. (In our informed consent form, we did note that the survey would ask about aesthetics, along with other topics such as meaningfulness of work, research culture, pandemic effects, etc.) We tried our best to achieve a high response rate for the study, including sending 14 reminder emails, postcards, iPad raffles, advertisements in *Nature*, requests to department chairs, and other measures detailed in the methodology report (pp. 17–19). Nevertheless, several invited respondents emailed the survey

firm to say they suspected it was a scam and wanted to be removed from the survey list. It is also likely that most invited participants did not even see the survey invitation, which the survey company sent by email. The survey firm also confirmed that in some institutions, an institutional spam filter was triggered which blocked our invitation from reaching any of the invited participants at that institution.

The problems we encountered have become increasingly commonplace in survey research. Declining response rates are a well-established problem by now. People today are simply less willing to take surveys than they used to be. Even leading survey organizations in the US such as the Pew Research Center, which is considered the trusted source for most public opinion data in the country, are now getting response rates below 10%. Researchers find, however, that even with smaller response rates, there is no evidence of increasing bias reflected in survey non-response (Gummer 2019; Leeper 2019).

Table 1 provides a demographic overview of the full survey sample. In the results that follow, we report descriptive statistics from biologists in the survey (N=1381) using survey weights which help overcome sampling bias to some degree and allow us to generalize to the target population. However, even the application of weights cannot completely eliminate all possible biases in the sample, so the results should be read with this caution in mind.

Table 1. Demographic overview of survey sample

Characteristic	N	Unweighted %	Weighted %
Country			
USA	535	15.5	54.4
UK	925	26.9	26.4
India	1345	39.1	9.5
Italy	637	18.5	9.8
Gender			
Female	1357	39.4	31.5
Male	2062	59.9	67.9
Other	23	0.7	0.6
Discipline			
Physics	1837	53.4	51.5
Biology	1381	40.1	38.1
Other	224	6.5	10.4
Position			
Postgraduate student	1370	39.8	27.1
Postdoc	465	13.5	14.4
Research scientist	282	8.2	4.8
Junior faculty	309	9	10.8
Mid-level faculty	359	10.4	11.5
Senior faculty	424	12.3	24.3
Other	233	6.8	7.1
Total	3442		

Table 2. Demographic overview of interview sample

Characteristic	N	%
Country		
USA	56	26
UK	53	24.7
India	51	23.7
Italy	55	25.6
Gender		
Female	103	47.9
Male	112	52.1
Discipline		
Physics	110	51.2
Biology	104	48.4
Other	1	0.5
Postion		
Postgraduate student	51	23.7
Postdoc	50	23.3
Research scientist	13	6.0
Junior faculty	35	16.3
Mid-level faculty	25	11.6
Senior faculty	30	14
Other	1	0.5
Left academia	10	4.7
Total	215	

In addition to the surveys, we also conducted in-depth interviews with scientists to explore the survey themes further (N=215). The majority of survey respondents were recruited from the survey sample, but we also sampled additional scientists, including some who had left academia, to better understand key survey themes. Table 2 provides demographics of the interview sample. In what follows, we present quotations from interview data with biologists in the four countries (N=104) that illustrate key themes in the survey.

3. Results

3.1 *What does 'beauty' mean to biologists?*

We asked scientists on our survey to identify what terms they associated 'beauty' in their scientific work. We presented them with 10 options, with the freedom to select as many options as were applicable to them, or

Table 3. Terms that biologists associate the with 'beauty' in their work

Inner logic of systems	58%
Hidden order or patterns	57%
Complexity	54%
Elegance	54%
Simplicity	43%
Pleasing colors or shapes	40%
Harmony	33%
Sense of fit	33%
Symmetry	29%
Asymmetry	14%
None of the above	2%

indicate 'none of the above' as their answer (table 3). These categories were developed after an initial set of pilot interviews with scientists in the four countries, as well as consulting the literature on aesthetics in science that we summarized above. The overwhelming majority (98%) selected at least one of the items on the list.

The majority of biologists associate beauty with the inner logic of systems (58%) and the hidden order or patterns (57%) they find in their work. Both of these indicators point to the sense of pleasure in grasping the underlying structures and causal mechanisms in natural phenomena.

One of our respondents, an associate professor of biology in India, described the beauty of the inner logics of systems in the following way:

> So the way that information is there in a cell and how without, if there's no perturbation or any disturbance, how every event in the life of that cell is actually chalked out … And it's also amazing that how functions are also there for different cells. I mean, a heart cell is supposed to be beating, nerve cell is supposed to be transmitting signals. You know how these information is just present as genes in the length of the D. N. A. It's amazing how like clockwork everything is working, is functioning and leading to the system and the whole organism to function (B-SV-PP-17-IN-1622).

Another respondent, a biology PhD student in the UK, describes the sense of hidden order she discovers in patterns in the data:

> I encounter beauty in science when you're at the point where you take the data and analyze it and then you see the patterns coming out and the beauty of it is in the apparent randomness that is only apparent randomness. It's not random at all. Yeah, something is going on behind that you can then uncover and learn about that. That is where I see the beauty (B-SV-AU-06-UK-12596).

Complexity is another aesthetic criterion that many biologists (54%) identified in our study. A full professor of biology in the United States explains the thrill she experiences in discussing the complexity of animal behavior, stating:

> It's really easy to just say like, oh, oxytocin is the cuddle hormone. I mean, that's why it's called the love hormone, but that takes away all of the depth and interesting things about it if you just say that, because that's not what it is. That's not at all what it is. I mean, the fact that it facilitates social bonds, but it only does that under certain conditions, right, certain social conditions, right? I mean, animals have to read the room. They don't just go up and lick everybody or smell every other animal. They have to weigh risks all the time and that's being weighed against their hunger and other [sic] and fear. … Why animals do what they do feeds into all that complexity, and I think that that is pretty awesome (B-SV-CK-07-US-19066).

Another full professor in biology in the US described finding beauty in the elegance of experimental design, remarking,

> I find beauty in elegance and simplicity of experimental design. The fewer moving parts and parameters an experiment can involve while still attacking a particular problem or being able to shed light on a particular question in a very specific way, I find that extremely beautiful … Maybe it's sort of an intellectual elegance, like a mathematical proof. So I love that (B-SV-BV-08-US-18680).

3.2 *Where do biologists encounter beauty in their work?*

We also asked scientists we surveyed where in their scientific work they encountered beauty, however they defined it (table 4). Again, respondents could choose more than one category. Here we found among biologists that the majority of them (75%) encountered beauty in the phenomena they study.

One PhD student in Italy explained how she views beauty in the phenomena she is studying:

Table 4. Where biologists encounter beauty in their work

Phenomena that I study (e.g., cells, particles, etc.)	75%
Teaching science	56%
The process of scientific research	51%
Scientific theories	49%
Scientific conference presentations	34%
Scientific journal articles	34%
My workplace	33%
Writings of prominent scientists	32%
None of the above	3%

> I am [a] biologist by heart … So therefore, genuinely every life form to me has some kind of beauty because it has a reason to exist. It found a niche. It generalized it's way up, but like it doesn't matter how it came to be, but it carries beauty within because it survived or evolved or developed (B-SV-BR-17-IT-8888).

Teaching science was another area where most biologists (56%) found beauty in their work. As a postdoctoral fellow in biology in the UK expressed it:

> I love being able to facilitate a student truly understanding … that to me is the most amazing thing about teaching: being able to see a student truly grasp on to a concept and make it their own (B-SV-AU-13-UK-12577).

We also found that 51% of biologists in the countries we studied found beauty in the process of scientific research. One postdoctoral fellow in the US told us:

> My research is microscopy based. It's very easy to find beauty in these cells and in these cellular processes. The images that I take can be very aesthetically pleasing (B-SV-OR-05-US-18887).

We also found that 49% of biologists find beauty in scientific theories. One assistant professor in biology from the UK described the aesthetic pleasure she gains from scientific theories:

> Anything that tries to explain nature, I find that is incredibly captivating, and this could be from the most known theories. [… For example], predator and prey. So, because there's a lot of predators there's going to be very few prey, and then as soon as the prey population decreases, then the predator population can also decrease, and then like a big cycle, to more complex or newer theories, I guess, which build on and transform the older ones, and suddenly something just makes more sense. And you're like, oh that's why this is happening! (B-SB-NS-13-UK)

Table 5. Aspects of the scientific process where biologists consider aesthetic considerations relevant

When I present or communicate scientific results	64%
When I analyze or interpret results	57%
When I conceive or design a project	56%
When I make observations in the lab or field	51%
When I develop hypotheses or theories	46%
When I develop a project plan or grant application	45%
When I confirm a hypothesis, theory, or model	34%
When I write code	20%
When I experience a lack of understanding	13%
When a hypothesis, theory or model fails	11%
When I do theoretical calculations	10%
None of the above	4%

3.3 *When do aesthetic factors matter to biologists?*

We also asked respondents where in the process of scientific research they find aesthetic factors such as beauty, awe, and wonder to be relevant (table 5). Here, the majority of biologists (64%) indicated that such factors were most relevant when it came to presenting or communicating scientific results.

An assistant professor in the UK explained why beauty is important for communicating scientific work clearly to reviewers and readers of articles:

> Preparing findings for publication is definitely, I think – you want something that's pleasing you, it needs to flow, it needs to culminate in something. And you want your figures to look appealing and, you know, it needs to be easily interpreted. And I think if something is more aesthetically pleasing, that's easier to do (B-SV-AU-05-UK-12614).

Another respondent, an assistant professor in the US declares that beauty plays an important role in teaching and helps students to learn better:

> I think aesthetics plays a huge role in teaching. I think down to like very practical considerations, like having beautiful slides will help students learn better than having ones that are disorganized or ugly, or having beautiful prose in your papers makes a difference too (B-SV-DJ-02-US-19169).

Biologists also indicated beauty as relevant when it came to analyzing or interpreting results (57%). For some respondents, such as one full professor in Italy, beauty provides her a sense of confirmation that her work is correct:

> There are some techniques that I think give a lot of satisfaction, … For example, I remember

> when I was doing hybridizations, you see the stain that you expect or the stain that gives you the confirmation that you are looking for, in the right place and in the right way. In short, a result that confirms what you're doing and so on. All this is beautiful (B-SV-BN-05-IT-6995).

Beauty is also relevant to most biologists (56%) when they conceive of or design a project. A full professor in the UK discussed how designing a project elegantly is critical for efficiency.

> If you throw enough resources at something you can crack your problem. But most of us as scientists don't have the funds to throw 40,000 replicates at a particular hypothesis. We have to do it with 40 replicates or 400 replicates if we're extremely lucky. So that requires a great deal of elegance in terms of how you efficiently design that experiment to be done with all the key components present and to provide a statistically solid test of your hypothesis but with an efficient use of resources, both in terms of your subjects, whether that be ants, sharks or whatever (B-SB-NS-12-UK).

Another respondent, an assistant professor in the US, shares how elegance in experiments helps him stay engaged and motivated is his work:

> I try to design – I try to set up an experiment, or if I have to, let's say, develop a reagent that I need to use to be able to do my experiment, I guess, I try to come up with sometimes an elegant way to do it. So in a sense, yes. And I don't know if I'm doing that just because maybe I find it motivating, but – so, it does in that regard. Because it's like, again, I think that there – for me, maybe this is kind of, comes back to beauty and maybe I'm conflating beauty and emotion a little bit, but I just think that you have to be, you have to be engaged with what you're doing, somehow, and so it definitely does (B-SV-BR-11-US-18405).

3.4 *What are the consequences of encountering beauty in scientific work?*

How do such aesthetic experiences affect scientists? What consequences do they have for recruitment, retention, and perseverance in scientific careers? We gathered scientists' opinions on these questions by asking them to select several possible statements that followed from their encounters with beauty in their scientific work (table 6). Again they could choose more than one option, and very few (4%) indicated they could not select any of the options.

We found that 65% of biologists say that encountering beauty in their scientific work motivates them to share this beauty through their teaching or mentoring. For instance, a postdoctoral fellow in India discusses the imperative to share the beauty of science by communicating the same emotional response to beauty that the scientist feels:

> When we teach, again we communicate to others. Just giving information is not – it will not be effective. We have to communicate excitement, that enthusiasm, euphoria, what we get when you see the beauty. So that can be conveyed only if you're seeing that beauty and if you appreciate the beauty, right? (B-SV-VN-19-IN-3746)

Another respondent, a full professor in Italy, asserts that scientists should appreciate nature for its beauty and not just its utility:

> Every time I find something interesting on social networks, a strange animal, a plant, I might pass it on to all the biotechnology students, because it seems to me that we should also look for the beauty of science, not just the useful (B-SV-BN-05-IT-6995).

For 60% of biologists, encountering beauty in science motivated them to become scientists in the first place. For example, a biologist in Italy who went on to leave academia, told us:

Table 6. 'Encountering beauty in my scientific work…'

motivates me to share the beauty of science through teaching or mentoring	65%
motivated me to pursue a scientific career	60%
helps me persevere when I experience difficulties or failure in my work	54%
improves scientific understanding	54%
motivates me to communicate science to the public	48%
feels similar to the beauty I encounter in forms of art (e.g., fine art, music, etc.)	47%
gives me more confidence in my results	32%
makes me think that I am on the right road to reach truth in my investigation	28%
has been life-changing for me	26%
suggests to me the existence of a higher power	16%
leads me to think I should re-check my work	12%
None of the above	4%

> [beauty] motivated me, because I sacrificed my private life a bit to follow this path of studies, transfers, changing houses and friendships in order to continue doing this job. It was the pleasure in doing it that motivated me to make certain choices (B-L-SS-01-IT).

A postdoctoral fellow in the UK discusses the importance of appreciating beauty and motivating her in her studies:

> At least this is the way that I got involved with plants and science in general. I think I had very good teachers and the way that they showed me the theory behind what they were teaching … You know the type of teacher that's like 'Whoa look at that.' And you see that the eyes are like really bright, because it will be beautiful. Then you will start seeing this because someone is fascinated about it … I had very good biology teachers and I think [that] was one of the very important things to make me go to biology … I think in biology we see beauty (B-SV-BR-14-UK-13321).

Another consequence of encountering beauty at work is perseverance. For 54% of scientists, encountering beauty helps them when they encounter failures and difficulties at work. An Indian postdoctoral fellow in India speaks about the importance of beauty for remaining motivated, since so many experiments fail:

> [M]any times we fail. See 90% of the experiments fail. So, what keeps us motivated? It must be that we have appreciated some beauty in our problem. That keeps us going every day even if problems, experiments fail 10 times, we go back and then do the experiment [for the] 11th time. That's because that, I don't know, the appreciation of that beauty in our problem is motivating me to go [on] (B-SV-VN-19-IN-3746).

3.5 *The importance and limits of beauty in science*

Overall, nearly 80% of biologists think that science helps us better access the beauty that actually exists in the world. For many of them, this is reflected in their motivation for becoming scientists and wanting to teach and communicate science with others – to better uncover and understand the beauty of nature through science. We also find that the majority (70%) of biologists believe that it is important for scientists to encounter beauty, awe, and wonder in their research.

Even though most of them value aesthetic criteria such as elegance when it comes to aspects of scientific work, they do not see it as strictly necessary in scientific research. Less than one-third of biologists (27%) think it is necessary for a good theory or experiment to be elegant. A PhD student in the UK gave us one such example from her field:

> I guess coming from ecology, … all we do is pretty ugly. Because you've got this beautiful planned fieldwork that should work magnificently, and then that day was raining so you're missing data and your data set is a complete mess, it's not beautiful by any stretch of imagination. And if you just hang on, on all the falls, then you're never gonna get anything out of it. Instead you have to be able to compromise and being like, 'Of course this is not as good as it could be, but you can still get stuff out of it.' So it's the same concept I guess with perfectionism, it has to be good enough to answer certain questions. So getting stuck into 'It has to be this perfect thing' might actually be counterproductive (B-SV-AU-07-UK-12699).

Another postdoctoral fellow in the UK describes how something does not need to be beautiful to be true:

> Beauty can help to get the truth, but ugly also can,' he told us. '[I]t doesn't need to be beautiful to lead to the truth … The reason why I say that is because, more than – In my career, more than 70% of the things we try in the lab will never be published and still, we gain truth in the ugly side … Because the nature of science is, most of the things we try or think, may not look as beautiful … but still lead to, you know, new knowledge (B-SV-NS-22-UK-12297).

4. Discussion and conclusion

'There is grandeur in this view of life,' Charles Darwin (2004, p. 490) marveled at the end of his *Origin of Species*, that 'from so simple a beginning endless forms most beautiful and most wonderful have been, and are being evolved'. Biologists today continue to marvel at the beauty they find in their work. Our study examined survey and interview data from scientists in the biological sciences working at PhD-granting institutions in the US, UK, Italy, and India, and found that most biologists consider aesthetic factors important in their work.

It is important to note again that our study is limited in several ways due to its focus on only these four countries, its restriction to primarily academic scientists, and especially the low response rate. While our study was branded 'Work and Well-being in Science' to avoid selection bias related to aesthetics, and our analyses applied weights based on the original sampling frame to correct for biases when generalizing to the target population, it is impossible to completely eliminate biases in our findings. (For instance, it may be possible that scientists who had the lowest levels of well-being systematically refused to participate in the survey.) So our findings should be read with these caveats in mind.

Our study found that while biologists' understanding of beauty may sometimes refer to conventional aesthetic criteria such as pleasing colors or shapes, they primarily associate beauty in their work with the hidden order and inner logic of systems. Nearly 70% of biologists reported that at least a few times a year, they 'felt surprised by discovering a hidden order or deeper systems underlying the phenomena I was researching'. Our findings resonate with the research of psychologists who argue that encounters with awe can open us to thinking holistically and in terms of systems (Keltner 2023). Our findings also support MacArthur's (2021) claim that biologists would be more likely to find beauty in complexity than simplicity (among physicists, by contrast, we found the opposite).

We find that encountering beauty in science is what leads most biologists in the countries we studied to pursue a scientific career in the first place. As Scarry (2013) argues, encountering beauty in the world makes us want to share it with others, so it is not surprising that most biologists consider beauty as a motivating factor for wanting to share it – which drives their desire to invest in teaching and mentorship. This finding also helps account for why most biologists see encountering beauty at work as an asset when it comes to persisting in the face of difficulties and failures in scientific work, which are experiences scientists must frequently contend with.

Most biologists also think that aesthetic factors matter in science communication, data analysis, and research design. Aesthetically pleasing patterns in the data confirm that one is on the right track, and clear communication adds to scientific understanding, and is vital for communicating science to students, colleagues, and to the public.

Biologists, unlike physicists, may not use aesthetic criteria such as elegance in a heuristic manner when it comes to theories – only a small fraction of biologists (11%) claim that an elegant theory is more likely to be true than one that is not. But they are more likely to see elegance as valuable in experimental design. As philosopher of science Catherine Elgin argues:

> An elegant experiment makes manifest what it achieves and how it achieves what it does. It exemplifies its scientific contribution. An inelegant experiment might disclose the same truth, but we would have a harder time recognizing that or appreciating how it did so. If the inelegant experiment is sufficiently complicated, it invites the worry that unappreciated confounding factors, rather than the hypothesis being tested, account for the result. The elegant result is more illuminating (Elgin 2020, p. 32).

Nevertheless, here, too, we find that not all biologists are in agreement – it may not always be possible to achieve elegant experiments especially in fieldwork where too many contingent factors are out of the researcher's control.

Research also finds that encountering beauty in science more frequently is associated with higher levels of psychological well-being among scientists (Jacobi *et al*. 2022). This relationship is understandable given our discussion above. The heart of the scientific quest is to achieve a greater understanding of the structures and causal mechanisms of the natural world, and the reward of understanding is a source of intense aesthetic pleasure. As Richard Dawkins puts it:

> The feeling of awed wonder that science can give us is one of the highest experiences of which the human psyche is capable. It is a deep aesthetic passion to rank with the finest that music and poetry can deliver. It is truly one of the things that make life worth living ... (1998, p. x).

The experience of beauty seems abundant in scientific practice in the biological sciences – not just in the phenomena that biologists study, but also especially in the *understanding* that is gained through scientific research. This beauty is intrinsic to scientific work. To help scientists thrive in their work, we need to create the conditions for them to continue to do good science, and to better address the institutional obstacles that get in the way of the beautiful quest for scientific understanding.

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Declarations

Conflict of interest The authors have no conflicts of interest to disclose.

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