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Characterizing First-Year Biology Majors' Motivations and Perceptions of the Discipline

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Understanding why students choose to major in biology provides important insight into the motivations of biology majors. It is similarly important to investigate how biology majors perceive the discipline, including associated activities, such as independent research, which can influence students' interests in the field and likelihood to persist in science, engineering, technology, and math. However, there has been little work done examining biology student motivations and perceptions, particularly at non-research-intensive universities or after the COVID-19 pandemic started. To address this gap, we surveyed the first-year cohort of biology majors at a private, comprehensive university. We found that students largely reported choosing the major because of interest in the field and/or the fact that the major would prepare them for specific careers. We also found that students had skewed conceptions of several major subdisciplines of biology (ecology and evolution; cell and molecular biology; and anatomy and physiology). Finally, most students reported not knowing what independent research is or presented naive conceptions of research. Our work offers a characterization of how first-year students at our university perceive the discipline, and we conclude by discussing changes that our program has made to address these results as well as implications for instructors and biology administrators.

KEYWORDS student choice of major, student perceptions of biology, independent research

PERSPECTIVE

Retention of students in science, technology, engineering, and math (STEM) remains a concern, with attrition particularly high early in a student's college career (1, 2). Many factors shape a student's decision to stay or leave STEM, including academic preparation, sense of belonging, and school culture and climate (2–4). While there have been many papers examining STEM student retention, two factors that influence student persistence remain underexplored: (i) students' reported motivations for choosing a major, and (ii) students' perceptions about the discipline.

These factors are important to explore in the context of biology programs, particularly at smaller, undergraduate-only programs typically found at colleges and universities which are not research intensive (R1). There are several unique challenges and opportunities facing these smaller undergraduate programs. First, understanding the motivations of why students at these programs choose biology as a major is critical, given that attrition of a small number of students may impact the program more than in programs with a larger number of students. Similarly, there may be fewer traditional course offerings in the program due to smaller programs likely having fewer faculty in the department, resulting in heightened importance of providing other opportunities for students to explore the breadth of biology. These challenges mean that it is critical to explore why students at smaller, primarily undergraduate institutions choose biology as a major and how they perceive biology as a discipline.

PREVIOUS SCHOLARLY ATTEMPTS AT EXAMINING STUDENT MOTIVATIONS FOR CHOOSING BIOLOGY AND PERCEPTIONS OF THE DISCIPLINE

Past work primarily focused on factors that shape students' choices of majors in STEM. Such work identified that the choice of major is influenced by many interrelated factors, including previous STEM course experiences and grades, knowledge and interest in different careers, and potential pressures from family and friends (5–11). In addition, demographic variables and experience with pre-college programs may also impact student choice of majors (12–17). Those previous studies have generally relied on interviews, surveys, analyses of demographic data, and course performance at larger R1 universities, and we are not aware of any work that has examined the self-reported motivations of a whole cohort of students at a smaller, undergraduate-only biology program (18–20).

Academic motivation has been identified as an important factor in college student retention (21). Assessing motivation can be challenging, since there are multiple theoretical frameworks

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behind motivation, which is recognized as a general term that encompasses several different variables and constructs (22, 23). Most studies that have examined motivation have focused on these constructs, such as goals, topic interest, and self-efficacy. Here, we use the term motivation in a more constrained manner, referring to students' self-reported reasons for choosing a biology major. This approach has been used in other STEM fields (24) and can provide direct insight into what students perceive as the main influences on their academic decision.

In contrast, there has been far less work done examining student perceptions of biology as a field, including how students define the field and view associated activities such as independent research. Past work primarily focused on student perceptions of teaching methods within STEM (25–27) and student affect (28, 29), rather than on characterizing how students perceive and define the field and its subdisciplines. There have been no previous attempts at characterizing how students define and perceive the term "independent research," with most work instead characterizing and assessing the experiences of students engaged in independent research (30–33). Examining student perceptions is important, because students' experiences and interests are likely driven by their perceptions of the field (34), which likewise shape their future motivations and participation in the field (9, 35).

STUDENT SURVEY TO DETERMINE MOTIVATIONS FOR CHOOSING BIOLOGY AND PERCEPTIONS OF THE DISCIPLINE

Our exploratory study was conducted at a private, comprehensive university in southern California. At our university, most students choose a major when applying for college and declare an area of study within biology (anatomy and physiology; ecology and evolution; or cell and molecular biology) at the end of their second year. First-year biology majors typically all take the same core courses, including introductory biology, and will not have taken any elective courses in the areas of study.

Our work focused on biology majors who are first-year students, students who have switched majors and are in their first year of being a biology major, or are transfer students in their first year at the university (here referred to together as first-year biology majors). These groups are of particular interest, since students who leave STEM are more likely to do so in their first year in college (36, 37). In addition, these first-year biology majors are all required to take a professional development seminar each spring. We surveyed students in this course, which is limited to biology majors, before the spring 2022 semester. Time was also provided on the first day of class for students to complete the survey. The study was reviewed and deemed exempt by the Chapman Institutional Review Board.

Responses to the free-response questions were read independently by two coders, who came up with codes following inductive, grounded theory (38). Categories were discussed until consensus was reached. After independently coding the responses, interrater reliability was calculated using ReCal 2.0 (39). Each question's Cohen's kappa was above 0.7, indicating substantial agreement (40). Disagreements were discussed to reach consensus. Interrater reliability was not coded for a question asking about perceptions of research in biology, since most students left this question blank or indicated that they did know what this meant. Given the low number of substantive responses, the coders instead independently read and discussed these responses and presented the qualitative summary of the themes here.

Demographics of first-year biology majors

In total, 52 students completed the survey, representing 91.2% of the 57 students enrolled in the class. This sample represented nearly all of the 60 students who started as a biology major in fall 2021 or spring 2022, including first-year students and transfer students. Thirty-two of the respondents (61.5%) indicated that they were female, while 19 of the respondents (36.5%) identified as male. The remaining students did not indicate their gender; there were no nonbinary students. We did not collect any additional demographic data from the students.

Students cited interest and career preparation as main reasons for choosing a biology major

We first asked students why they chose biology as a major. The majority (59.6%) of respondents indicated that they chose the major because of interest in the discipline, demonstrating an intrinsic academic motivation (41). The second most common response (48.1% of respondents) was that they chose the major since it would prepare them for a given career. The majority (80%) of students who cited this reason explicitly identified a health occupation (e.g., physician or dentist) that the major would prepare them for. This response aligned with past work demonstrating the large influence of careers on students' choice of majors (42). The influence of careers is likely a combination of both internal and external motivators (43). For instance, career choice can be driven by genuine enjoyment and satisfaction from a career (internal) and/or familial pressure, socioeconomic status, and earnings potential of a career (external) (42). Our results do not provide insight for why students were motivated to pursue given careers or how this influenced their choice of major. However, we note that over half of the students who cited a career as their reason for choosing biology also cited an interest in biology. More work is needed to investigate if the students who only stated that they chose the major because of its alignment with a career without also mentioning interest in biology were driven more by extrinsic rather than intrinsic motivation and if there are differences in STEM retention between these groups. The only other reason cited by more than one student was family (9.6% of students), where their choice of major was influenced by familial occupations relating to biology or familial expectations to pursue a science degree.

Students reported skewed conceptions of the subdisciplines of biology

We next explored student conceptions of three major subdisciplines of biology: anatomy and physiology, ecology and

TABLE 1
Student perceptions of anatomy and physiology

Code name	Description	% of respondents[a]	Sample student quote
Human	Explicitly defined the field as a study of humans or an aspect of human biology	53.5%	"It has to do with the human body, its components, and how they work together."
Structure and function	Characterized the field as examining structure and/or function of organisms or their specific systems	20.9%	"The study of the structures of organisms and how they function."
Body	Defined the field as the study of the body or investigating the biology of the body, without explicitly mentioning humans	20.9%	"Anatomy is the study of the body. Physiology is the study of how the body works."
Career	Perceived the field as useful for a specific career or occupation	9.3%	"I would characterize it with this [sic] who would like to pursue medicine or a career in physical therapy or kinesiology."
Animals	Cited the field as the study of nonhuman animals	7.0%	"The study of the function and motion of animals."

[a]The percentages total to more than 100% because one response could contain more than one thematic code.

evolution, and cell and molecular biology. Students were asked "How would you define or characterize this field of biology?" for each of these subdisciplines.

Anatomy and physiology. Our results showed that students held skewed conceptions of anatomy and physiology. For instance, anatomy is defined as the study of "internal and external structures of the body and their physical relationships" (44), while the American Physiological Society defines its field as "a broad area of scientific inquiry that focuses on the biological function of living organisms" (45). However, only one-fifth of respondents cited this subdiscipline as encompassing structure and function, with another fifth indicating that the subdiscipline of anatomy and physiology involves the study of bodies, aligning with expert definitions (Table 1). In contrast, over half of students perceived the subdiscipline as being grounded in the study of humans, which was the most common response. This response demonstrated that many students equated this subdiscipline with human anatomy and physiology, despite the field encompassing a broad range of study organisms, including plants, animals, and more. Similarly, nearly 10% of respondents indicated that they viewed this subdiscipline as involving animals, aligning with high levels of plant and nonanimal organism blindness (46).

Ecology and evolution. Student conceptions of ecology and evolution largely matched expert definitions, though they still exhibited several biases. For instance, the Ecological Society of America defines ecology as "the study of the relationships between living organisms, including humans, and their physical environment" (47). Students largely perceived ecology as relating to the environment or interactions between organisms (Table 2), in agreement with expert conceptions.

Students primarily characterized evolution as involving change. However, this is harder to compare to expert conceptions, given that the Society for the Study of Evolution defines its scope as "the study of organic evolution and the integration of the various fields of science concerned with evolution" and does not provide a more specific definition (48). Several textbooks characterize evolution as change in genetic characteristics or descent with modification (49). However, none of the students identified changes in DNA or genes, nor descent with modification, as their characterization of the field. Students instead associated evolution with the history of life (20.5% of students) and showed a bias toward animals and plants in their responses, with no other taxa mentioned (Table 2). While studying the history of life is part of evolutionary biology, it is not the only aspect of the discipline, which encompasses studying evolution across all organisms.

Cell and molecular biology. Students showed alignment with expert definitions of cell and molecular biology (Table 3), though this is the only subdiscipline we investigated where both experts and students defined the field using derivatives of the name. For instance, the American Society of Cell Biology characterizes itself as a "community of biologists studying the cell, the fundamental unit of life" (50), and the American Society of Biochemistry and Molecular Biology states that its mission is to "promote the understanding of the molecular nature of life processes" (51). The most common response students provided—that cell and molecular biology is grounded in the study of cells and molecules—is thus aligned with expert definitions of the field. Students also cited structure and function of cells and molecules, again aligned with expert definitions. Interestingly, nearly 10% of students associated cell and molecular biology with chemistry, potentially aligning with biochemistry.

Students reported knowing very little about independent research

Independent research is a term commonly used in scientific literature (30, 52, 53) and is generally defined as the discovery of new knowledge or insight using the scientific process (54). To see if students' conceptions of research matched with expert definitions, students were asked: "Have you heard of independent research in biology? If so, how would you define independent

TABLE 2
Student perceptions of ecology and evolution

Code name	Description	% of respondents[a]	Sample student quote
Environment	Identified the field as the study of the environment or ecosystem	59.0%	"It characterizes with those who would like to [pursue] careers finding ways to improve the environment or with those who have an interest in the planet and animals."
Change	Mentioned that the discipline involves studying change	48.7%	"I'm not completely sure, but I would say relating to the environment and animals and how things have changed over time."
Interactions	Discussed the field as involving interactions	30.8%	"The relationship between organisms and how each part of an environment contributes to a balance."
History of life	Described the subdiscipline as centered around the history of life, including how life began	20.5%	"I would define this as the study of how life began and evolved and these organisms interact to form an ecosystem."
Animals	Specifically cited animals in their responses	15.4%	"Focused more on animals, nature, and a history of how/why things look, act, or function today."
Plants	Specifically cited plants in their responses	5.1%	"This has to do with animal species and plant species?"

[a]The percentages total to more than 100% because one response could contain more than one thematic code.

research in your own words?" Our results demonstrated that most students (65.4%) reported not knowing what independent research in biology is, either leaving the question blank or indicating that they were not aware of what research entailed. Almost no students provided a response indicating that they viewed independent research as generating new knowledge. Instead, students provided a more naive view of the term, with multiple students conveying that they thought the term meant that they would have to do work with very little guidance or mentorship. One student cited how they perceived independent research to be "research done by a student with minimal supervision," while another wrote how "independent research is when students find a topic they are interested in and usually, with a few other students, delve deeper into the topic and research it to create a final proposal." Several students also characterized research as gathering more information about a topic using online and library resources. Only one student characterized research as the generation of new knowledge, writing that research is "coming up with a research topic and completing your own tests outside of a defined class." In sum, students were likely focusing on the term "independent" and interpreting this in a different manner than most experts do, suggesting that "independent research" may not be the clearest way to describe undergraduate research conducted outside of a class.

POTENTIAL NEXT STEPS FOR THE BIOLOGY EDUCATION COMMUNITY

While our study was exploratory and limited to one cohort of biology majors at a single institution, our work provides the first characterization of biology majors' perceptions of the

TABLE 3
Student perceptions of cell and molecular biology

Code name	Description	% of respondents[a]	Sample student quote(s)
Cells and molecules	Provided a characterization of the subdiscipline that explicitly referred to cells and molecules	53.1%	"Looking at the cell and what it is made up of." "Focused more on how organisms function on a cellular level."
Structure and function	Mentioned cellular or molecular structure and function	26.5%	"Cellular and molecular biology focuses on the structure and functions of things such as cells or molecules."
Size and scale	Defined the subdiscipline around a microscopic size or scale	24.5%	"The microscopic side of biology, dealing with atoms and molecules."
Chemistry	Characterized the subdiscipline as linked to chemistry	8.2%	"It characterizes with those who are more interested in the chemistry aspect of biology and with those who have an interest in research or being in the lab."

[a]The percentages total to more than 100% because one response could contain more than one thematic code.

field that we are aware of. This is particularly relevant given that our work was done at a smaller biology program with only undergraduates and that the majority of biology education research has been conducted at large, research-intensive universities (55).

We highlight here some steps that our biology program has taken to address each of the biases identified in our study, as well as future steps for the biology education community:

- **Explicitly highlight career options and provide opportunities for students to explore possible careers early on.** Given that a significant portion of students cited that they chose the biology major to prepare for a given career, it is important to highlight the breadth of possible career options for biologists. Our program has developed a professional development course for first-year biology majors that includes career panels, and our college will be offering another course on identifying and landing internships. Similarly, the university has launched several initiatives to better communicate career options to prospective students, such as developing web pages that discuss possible careers. We call on biology programs to emphasize possible careers to prospective students, which may attract some students who otherwise may not have recognized the possibilities, and embed more career exploration for current students.
- **Clarify what biology subdisciplines encompass.** This study found that students had skewed and more narrow conceptions of biology subdisciplines than the broader scientific community. These conceptions may impact students' likelihood to pursue studying that subdiscipline. In response, we have included panels of faculty specializing in these areas into introductory courses to challenge students' biases of these subfields. Similarly, our program has begun examining how well our learning objectives map onto the curricular map and are planning on doing the same for Vision and Change core concepts (56). These efforts will ensure that students are introduced to different core concepts, spanning subdisciplines of biology, early and often. We urge other educators to clarify the scope of these subdisciplines and challenge students' biases. This is of particular importance in programs with different tracks aligned with these subdisciplines, since students may make their choice based on their perceptions.
- **Discuss what independent research is and provide opportunities to explore research early.** Student participation in research can be transformative and leads to a wide range of benefits, such as increased scientific abilities and interest in STEM (57). However, our results showed that very few first-year biology students recognized what research is or what most faculty mean when they discuss independent research. This may present a large barrier in attracting students to such research experiences. In response, we have launched several "fireside chats" and panels about research with faculty and students describing their experiences, successes, and challenges to demystify research. We have also written a guide to research, which covers what research is and how to get involved, on the biology majors' home page. Finally, we have included additional discussion of research experiences in our introductory courses. We call on other educators to either discuss research or provide students with early experiences in research (58).

Finally, there is a need for more research to assess the impacts of such interventions and explore factors that shape student perceptions more in depth. For instance, our exploratory study was limited to characterizing student perceptions at one time; future studies can survey students longitudinally and determine what factors shape these perceptions as students progress in college.

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