

What Are Undergraduates Doing at Biological Field Stations and Marine Laboratories?

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Biological field stations and marine laboratories (FSMLs) serve as places to study the natural environment in a variety of ways, from the level of the molecule to the globe. Undergraduate opportunities at FSMLs reflect the diversity of study options—formal courses, research and service internships, and field-trip experiences—and students are responding to those opportunities: More than half of the FSMLs that responded to an informal survey indicated an increase in their undergraduate enrollment in the past 10 years. Many programs are residential in nature, which facilitates the development of a community of scholars in which undergraduates can interact not just with their peers but also with graduate students, research assistants, postdoctoral fellows, and resident and visiting faculty. With respect to undergraduates, challenges for FSMLs include maintaining relevance in curricular offerings, attracting rigorous and well-trained instructors, providing adequate numbers of mentors for research experiences, and providing funding to assist undergraduates who want to study at a FSML.

Keywords: field stations, marine laboratories, undergraduate education, teaching, internships

Teaching undergraduate students at biological field stations and marine laboratories (FSMLs) has a long history. Some of the most prestigious American marine stations, such as Friday Harbor Laboratories, the Scripps Institute of Oceanography, the Marine Biological Laboratory at Woods Hole, and Hopkins Marine Station, began as undergraduate teaching institutions (Maienschein 1985, Benson 1988). Likewise, in the terrestrial realm, several long-established field stations—including Flathead Lake Biological Station, the Mountain Research Station, the Rocky Mountain Biological Laboratory, the University of Michigan Biological Station, and the Mountain Lake Biological Station—have their origins as undergraduate teaching sites.

Although FSMLs have grown to encompass more diverse missions such as research, conservation, and outreach, they still are where undergraduates go to receive instruction in a wide range of biological sciences. Appealing as both a venue for research and an educational setting, FSMLs offer immediate access to a diversity of habitats and organisms. Equally important is the provision of protected areas for long-term study, either on FSML property or in adjacent protected areas (Lohr et al. 1995). These adjacent areas often take on a greater significance for protection in the plans of their respective managers because of the presence of the FSML and the activities it conducts. In many cases, the long-term data sets that FSMLs maintain can enhance both teaching and research activities.

Undergraduate education opportunities at FSMLs are diverse—they include, among other things, formal courses, research experiences, and internships (see box 1)—yet they share several characteristics: In many instances, student-to-faculty ratios are low, making it possible for students to receive considerable mentoring from faculty. The presence of graduate students also provides additional opportunities for academic interactions. Such mentoring can enhance student performance in courses and research activities, and may even influence a student's decision to pursue a career in science, technology, engineering, or mathematics (Lopatto 2007). Many programs are residential: Students live at the FSML with permanent and visiting faculty and researchers. These characteristics foster the development of a community of scholars in which undergraduates may interact with their peers, graduate students, research assistants, postdoctoral fellows, and resident and visiting faculty. Moreover, FSMLs are an ideal setting for students' practice of the art of discovery (Eisner 1982). Considerable anecdotal evidence shows that many of today's scientists, conservationists, and naturalists were "turned on" to their profession by a FSML experience during their undergraduate career (Gladfelter 2002).

In the course of writing this article, I asked FSMLs for information about their undergraduate programs. I sent this informal survey to the 343 e-mail addresses on the Organization of Biological Field Stations (OBFS) listserv and to about 100 addresses on the National Association of Marine

Box 1. Opportunities for undergraduates at Oregon's field stations and marine laboratories.

An examination of Oregon's largest field stations and marine laboratories (FSMLs) provides a case study of the diversity of opportunities available for undergraduates, and exposes some of the challenges that FSMLs face in developing and sustaining successful programs for undergraduates.

The H. J. Andrews Experimental Forest, located in the Cascade Mountains east of Eugene, is administered cooperatively by the US Forest Service's Pacific Northwest Research Station, Oregon State University, and the Willamette National Forest, and it is part of the Long Term Ecological Research program of the National Science Foundation (NSF). Although the Andrews Forest is best known for the key role it has played in the development of forest ecosystem science and management over the course of several decades, education is also an important component of the mission. The strength of the Andrews Forest undergraduate education program arises through field research experiences. Undergraduates can participate in the NSF Research Experience for Undergraduates and the Eco-Informatics Summer Institute. Each year, more than 600 undergraduates participate in field-module courses that last from one day up to several weeks and are taught by faculty from approximately 20 colleges and universities.

The Hatfield Marine Science Center (HMSC) in Newport, Oregon, is 55 miles from the Oregon State University campus. The HMSC has research facilities that support investigations in marine fisheries, aquaculture, ocean energy, water quality, marine biology, botany, microbiology, zoology, and oceanography. Undergraduates have opportunities for a variety of research and internship experiences; they are taught not only by university faculty members but also by adjunct and courtesy faculty from agencies colocated at the HMSC, including NOAA (National Oceanic and Atmospheric Administration), the Environmental Protection Agency, the National Marine Fisheries Service, the US Fish and Wildlife Service, and the Oregon Department of Fish and Wildlife. In addition, HMSC has a well-developed visitors' center that provides undergraduates with internship opportunities in informal science education. Multiple colleges and departments offer courses at HMSC, and on average 35 undergraduates are in residence during each term. The presence of an academic program coordinator is key to providing coordination, support, and advocacy for undergraduate programming at HMSC.

The University of Oregon's Institute of Marine Biology (OIMB) is in Charleston, Oregon, 125 miles from the main campus in Eugene. The institute has offered programs for undergraduates since its founding as a summer field camp in 1924; year-round programs were instituted in 1968. Approximately 100 students participate in the residential program each year. The strong focus on undergraduate teaching that began with OIMB's founding in 1924 continues to this day. A key to the success of this program is the quality course work and research opportunities that take advantage of the diverse habitats surrounding the institute, and this work and research satisfy requirements for degree programs. The University of Oregon is one of the few institutions on the West Coast offering a marine biology degree; as part of their degree program, undergraduates are required to attend three terms at OIMB. The summer teaching program continues to thrive because of dedicated visiting faculty who supplement resident faculty members' teaching during the academic year. The presence of an academic coordinator is key to supporting the undergraduate programming. (continued)

Laboratories (NAML) listserv (some marine laboratories belong to the OBFS, so there was a small amount of duplication). The OBFS and NAML comprise a diverse array of organizations, including many that do not have programs for undergraduates (e.g., research preserves and science, fisheries, and forest research centers). Eighty-eight FSMLs that do offer programming for undergraduates responded to the informational request (results are available at <http://obfs.org/purl/200906121>). Response bias was probably present in this sample, as FSMLs with successful undergraduate programs were more likely to report than were those with struggling programs. The number of undergraduates attending a FSML varies widely, ranging from 6 to 5000 per year, but 37 of the 78 FSMLs that reported student numbers serve fewer than 100 undergraduates per year (figure 1). The wide variation in numbers reflects the diversity of FSML programs. The most common FSML offerings for undergraduates are formal courses and research experiences, which in many instances are combined with a service component (table 1). Many FSMLs are also used as a site for short field trips for faculty who teach on the main campus or at other institutions.

Formal courses, most of which are given in the summer, are a long-time feature of FSML education offerings; 67% of

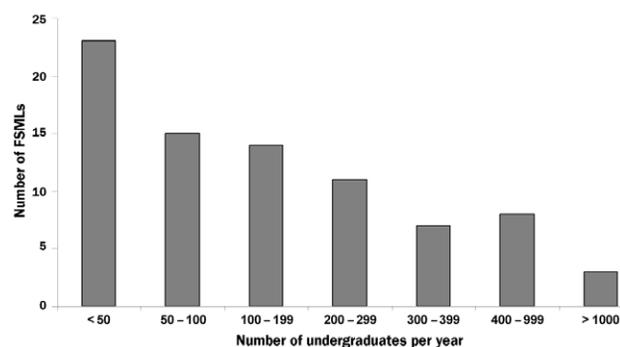


Figure 1. Number of undergraduates attending field stations and marine laboratories (FSMLs) in 2008. Data are from 78 FSMLs responding to an informal survey conducted February 2009.

responding FSMLs offer such courses. Sixty-five percent offer courses for upper-division students, and 41% for lower-division students; 39% offer courses for both levels. Both the OBFS (www.obfs.org) and the NAML (www.naml.org) maintain Web pages that list the courses offered by their member institutions. In 2008, the NAML listed 15 institutions offer-

Box 1. (continued)

The challenges for these three institutions are similar. To offer quality programs, they need sufficient resident and visiting faculty to mentor research students, the ability to attract faculty to teach courses, and funding for undergraduates to spend time at a FSML. A key factor that has enabled development of sustainable programming at the two marine stations is a full-time academic education coordinator. Practical realities common to all three institutions can deter undergraduates from enrolling in FSML programs, however. For example, depending on the distance between a FSML and the main campus, and on the housing accommodations an FSML has available, a student may have to find temporary housing for the duration of a FSML experience, which can be a practical and financial burden, especially during the academic year when students may also have to maintain a room at the main campus. Even for the two FSMLs that are within commuting distance of their main campuses (HMSC and Andrews Forest), transportation between the FSML and main campus can be a problem, and students who do commute are often at a disadvantage when it comes to participating in some of the activities that promote the community-of-scholars interactions that are common at FSMLs.

Opportunities for undergraduates at Oregon FSMLs.

Undergraduate programs	HJ Andrews Forest	Hatfield Marine Science Center	University of Oregon's Institute of Marine Biology
Research experiences	National Science Foundation site REU program: Pollination Biology Research Experiences for Undergraduates; NSF Eco-Informatics Summer Institute (EISI); Individual NSF investigator REU	NSF REU site program: From Estuaries to the Deep Sea; NOAA Fisheries Internships; Promoting Research Investigations in the Marine Environment internships for community college students	Individual NSF investigator REU; Minority Access to Research Careers summer interns (SPUR program); Promoting Research Investigations in the Marine Environment internships for community college students
Upper-division courses		Residential courses in fall, spring, and summer terms for fisheries and wildlife; biology and environmental science majors	Residential courses in fall, spring, and summer terms for marine biology, biology, and environmental science majors; support for visiting courses from main campus
Lower-division courses		Short courses for majors and nonmajors	Short courses for majors and nonmajors
Other undergraduate opportunities	Field module courses taught by faculty from visiting colleges and universities; environmental leadership program site for environmental education undergraduates; field assistant positions	Certificate program in aquarium science in partnership with Oregon Coast Community College; undergraduate internships at HMSC Visitor Center and Library; state and federal agency internships; support for visiting universities and colleges to run field courses at HMSC	Environmental leadership program site for environmental education undergraduates; undergraduate teaching assistantships; support for visiting universities and colleges to run field courses at OIMB
Funding sources for undergraduates	REU internships; EISI internships; research grants	Oregon State University HMSC awards, scholarships and fellowships; REU internships; HMSC visitor center internships; NOAA undergraduate internships/scholars; PROMISE internship; NSF Centers for Ocean Science Education Excellence funds	University of Oregon scholarships; REU internships; SPUR internships; NSF Centers for Ocean Science Education Excellence
Program Web sites	http://cropandsoil.oregonstate.edu/REU/ ; http://eco-informatics.engr.oregonstate.edu/ ; http://andrewsforest.oregonstate.edu	http://hmsc.oregonstate.edu/ ; www.coseepacificpartnerships.org/ ; http://oregonstate.edu/promise/ ; www.occc.cc.or.us/aquarium	www.uoregon.edu/~oimb/ ; www.coseepacificpartnerships.org/ ; www.uoregon.edu/~ecostudy/elp

Table 1. Opportunities for undergraduates at field stations and marine laboratories (FSMLs).

Undergraduate opportunity	Percentage of FSMLs (n = 88)
Formal courses for freshman/sophomores	41
Formal courses for juniors/seniors	65
National Science Foundation Research Experiences for Undergraduates (REU) site program	21
REU experience with individual investigators	33
Other research experience opportunities	72
Joint research and service internships	61
Service-only internships	22

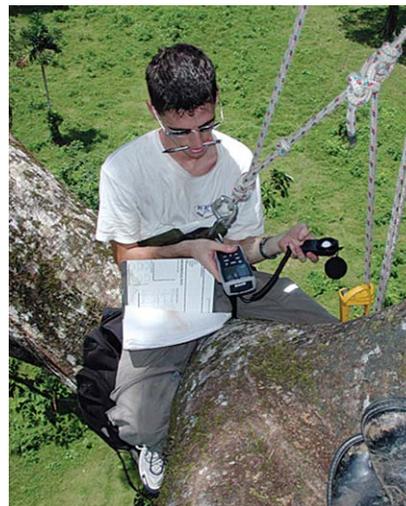
ing undergraduate courses and the OBFS listed 24, 6 of which appeared also on the NAML list. These 33 institutions listed roughly 400 different courses for undergraduates. These institutional databases are not comprehensive, however, and a search of individual FSML Web sites adds considerably to the number. Fifty-two percent of the responding FSMLs reported an increase in enrollment in their courses in the past 10 years, whereas only 13% indicated that their undergraduate enrollments had declined. The most common reasons for this growth in FSML course enrollment were increased enrollment in general at institutions offering FSML programs, better planning to ensure that courses fulfilled requirements, addition of new faculty with an interest in field courses, and the addition of new programs and more targeted advertising. Declines were attributed primarily to higher costs for students.

The diversity of courses is wide: Some are general courses that offer undergraduates exposure to basic biological concepts such as ecology, evolution, molecular biology, and physiology; other, more specialized courses offer undergraduates and graduate students in-depth experience with a taxon, technique, or newly emerging topic. Recent examples of such offerings include a course on acrocarpous mosses of the northern woods, offered by the Humboldt Field Research Institute in Maine; the bee and ant courses at the American Museum of Natural History's Southwestern Research Station in Arizona; cold-water diving at the University of Alaska's Kasitsna Bay Laboratory; coastal ecotoxicology and pollution at the Duke Marine Laboratory; and the biology of climate change, offered by the Rocky Mountain Biological Laboratory. In some instances, FSMLs are the only source for instruction in the classical courses of organismal biology, which often include the study of a region's flora and fauna. Courses that are rarely part of the curricula of the main campus, such as invertebrate zoology, insect biology, mammalogy, and ornithology, are offered at FSMLs, and in many cases FSMLs are the only place where undergraduates can take these courses (table 2). Process-oriented courses are also common at FSMLs; many FSMLs offer courses in the ecology of their representative habitats. In recent years, FSML offerings have expanded to include conservation-oriented courses, as Brussard (1982) advocates.

Table 2. Availability of traditional course offerings at field stations and marine laboratories (FSMLs) and comparison with availability on main campuses.

Course	Number of FSMLs offering the course	Number of courses taught at the main campus associated with the FSML
Botany	15	12
Herpetology	6	5
Ichthyology	18	12
Insect biology	9	4
Invertebrate zoology	23	12
Mammalogy	14	6
Ornithology	14	8

Despite the broad range of courses, there is some commonality in the nature of the course structure and in the types of pedagogy FSML professors use. The size of the class is small, often under 15; this class size allows considerable interaction among students and professors, which can result in greater student achievement (Follman 1994). Course participants often meet for full days, several days a week, and spend a lot of time in the field. In most instances, faculty are responsible for teaching all components of the course—whether at the lectern or in the laboratory or field—unlike the case at many larger campuses, where teaching assistants carry out laboratory instruction. Hands-on and experiential active learning are common pedagogies, and students are often involved in individual or group work. For many students, this will be their first experience with either guided or open-ended inquiry. Undergraduate students who do not have the



Student takes light-intensity readings from the crown of a ceiba tree, 150 feet above the ground. This exercise was part of his independent research project, which examined the correlation between light intensity and the presence and diversity of epiphytes. Photograph: Peter Lahanas.

opportunity to serve as a research apprentice can undertake research firsthand in a FSML course, where learning takes place not only in the classroom but also in the laboratory and field. Studies in more formal laboratory settings have shown that students who experience course-embedded research can see positive learning gains similar to those made by students who undertake an individual undergraduate research experience (Trosset et al. 2008). Eighty-eight percent of FSMLs reported that some or all of their courses fulfill the core requirements of a biological science major—an important detail for undergraduates who want to complete their degrees in a timely fashion and cannot afford to take courses that do not fulfill requirements for their degree.

Field stations and marine laboratories outside the United States also play an important role in education (Whitesell et al. 2002). For North American students, FSMLs in the Caribbean and in Central America are important centers for gaining experience in tropical biology. Of particular note are the three field stations in Costa Rica administered by the Organization of Tropical Studies (OTS), which offer research and study programs for undergraduate students interested in field biology. Caribbean marine stations provide students with opportunities to learn about tropical marine environments: For instance, the Bermuda Institute of Ocean Sciences, the Council on International Educational Exchange Research Station in Bonaire, and the Dominican Institute of Tropical Marine Ecology offer courses and research opportunities in tropical marine biology.

Field stations and marine laboratories are national resources that not only support the institutions with which they are affiliated but also offer their facilities and staff to undergraduates from the many colleges and universities in the



Oregon State University marine biology students collecting invertebrates on the Yaquina Bay mudflats with Sally Hacker, assistant professor of zoology and instructor for the 16-credit, intensive marine biology course offered during the spring term at the Hatfield Marine Science Center. Pictured from left to right: Kenny Binder, Sally Hacker, Keely Lopez, and Kaitlyn Mcleod. Photograph: Margot Hessing-Lewis.



Students installing grid markers for experimental seeding of native grasses and long-term monitoring of grassland plants at the University of California's Hastings Reserve in Carmel Valley. Pictured from left to right: Maya Villarreal (now an environmental scientist at AMEC Earth and Environmental, Inc.) and Keri Holland (a postdoc at the University of California, Santa Barbara). Photograph: Mark R. Stromberg.

United States that are not affiliated with a FSML. The majority of course offerings at FSMLs are open to all qualified students regardless of their home institution, and many FSMLs also make their facilities available to visiting groups for either short- or long-term use. For example, the Smithsonian Institution's Bocas del Torro Research Station in Panama hosts a number of visiting groups from the United States who use the facilities to teach a variety of tropical courses. Here at the Oregon Institute of Marine Biology (OIMB), in addition to running year-round programs for undergraduates and graduate students, each year we host 10 to 12 additional groups from US colleges and universities for periods of days to months. Field stations that are not directly affiliated with an educational institution also play an important role in this regard. Archbold Biological Station, for example, each year hosts classes of varying size for students from 10 to 12 colleges and universities. At OIMB, groups that stay more than two days generally range from 10 to 25 individuals. Groups that come for a one- or two-day visit, however, can be much larger—for example, some colleges and universities use OIMB and many other FSMLs as field-trip sites for classes that may comprise more than 100 students.

More and more, undergraduates are interested in participating in intense study programs that immerse them in scientific disciplines. Field stations and marine laboratories have played an important role in facilitating some of these programs. The eight-month-long Three Seas Program, which gives students the opportunity to spend a year studying marine biology in three different marine environments, is one such example: The participating FSMLs are Northeastern University's Marine Science Center; the Gump Marine

Station on the island of Moorea, operated by the University of California, Berkeley; and the University of Southern California's Wrigley Marine Science Center on Catalina Island. Another example of a program that uses FSMLs as bases for its field studies is Williams-Mystic, the maritime studies program of Williams College and Mystic Seaport; field studies take place at Bodega Marine Laboratory, the Oregon Institute of Marine Biology, and Louisiana Universities Marine Consortium Laboratory.

Participation in research is widely believed to encourage undergraduate students to pursue advanced degrees and careers in science, technology, engineering, and mathematics (Russell et al. 2007). Research experiences have been shown to improve undergraduates' understanding of science, stimulate academic motivation, and increase retention rates, particularly for minorities (Locks and Gregerman 2008). Field stations and marine laboratories have a long history of offering opportunities for undergraduate research. Almost all of the respondents to the survey reported that their FSML supported undergraduate research opportunities, and 62% stated that undergraduates' participation in research had increased in the past 10 years, with participation declining only at one FSML.

The availability of external funding was the explanation most often cited for the growth in undergraduate research opportunities. Twenty-two FSMLs currently have funding from the National Science Foundation (NSF) to conduct site programs in Research Experiences for Undergraduates (REUs; www.nsf.gov/crssprgm/reu/reu_search.cfm), and 33% of the responding FSMLs offer opportunities for individual NSF-funded REU experiences with resident or visiting FSML

faculty. The NSF REU model places individual students with faculty mentors for (usually) a 10- to 12-week period of research and mentoring. Seventy-two percent of FSMLs run additional undergraduate research internship programs, and 61% present opportunities for joint research and service internships. Some of these programs follow models that differ from the traditional NSF REU program; for example, the Friday Harbor Marine Laboratory offers a research apprenticeship program for undergraduates and post-baccalaureates, in which teams of 5 to 12 students work on one focused research problem guided by a group of faculty and postdoctoral and graduate-student mentors (Willows 2004). The research internships at Archbold Biological Station combine an independent research experience with assigned duties that include training in collecting and managing data, conducting statistical analyses and literature reviews, or curating collections.

Field stations and marine laboratories face several challenges with respect to undergraduate education, despite the proven benefits of FSML experiences for students. One growing concern is the escalating cost of higher education and the increasing need for undergraduates to work during the summer months to support their education costs. For many reasons, the summer term is often the time of highest activity at FSMLs. The rising costs of education thus restrict the number and diversity of students who can take advantage of a FSML experience. Some FSMLs have been able to expand their offerings for undergraduates to other times of the year, including targeted week-long and weekend courses that allow students to spend time at a FSML while they are enrolled in main-campus courses. Seventy-four percent of FSMLs provide some type of funding assistance for their undergraduate programs, although in most cases, the number of undergraduates given funding each year is quite small. Only 5 of these FSMLs offered aid to more than 20 undergraduates per year; 24 give aid to fewer than 7 students per year. The amount of aid available for undergraduates at FSMLs reflects these differences. Annually, the range of aid available was \$500 to \$120,000, though only 4 of the 77 FSMLs were able to spend more than \$50,000 for undergraduates.

Many FSMLs are making efforts to provide opportunities for undergraduates, particularly those students who will contribute to greater diversity in the next generation of scientists. The FSML REU programs are helping, and a few other initiatives are under way, to give underrepresented students options for a FSML experience. The Multicultural Initiative in the Marine Sciences: Undergraduate Participation, or MIMSUP, program at the Shannon Point Marine Center is one such example. The Ecological Society of America's SEEDS (Strategies for Ecology Education, Diversity and Sustainability) program, which provides opportunities that stimulate and nurture the interest of underrepresented students in ecology, has used a number of FSMLs for field-trip activities. Undergraduates from community colleges make up one group that appears to be especially underrepresented at FSMLs (Klug et al. 2002). Forty-six percent of all under-

graduates in the United States attend a community college, and 35% of community-college students belong to a minority group (Phillippe and Sullivan 2005). Few community colleges are associated with a FSML, however, and only a small number of FSMLs offer opportunities for community-college students, many of whom have limited financial resources and thus may find it difficult to participate in a FSML experience.

Attracting undergraduate students to FSML programs can be a challenge. Many students are not aware of FSML opportunities when they are planning their undergraduate career, and so may not even consider the possibility of studying away from the main campus for a term. Faculty and advisers on main campuses can play an important role by interacting with students who would benefit from a FSML experience and giving them information on how a term at a FSML could benefit the student and fit into the student's degree and career plans. Many faculty members, however, have not had a FSML experience themselves, and thus may not think to suggest this opportunity to a student, or they may not consider using a FSML as a site for undergraduate instruction or research.

Field stations and marine laboratories have multiple ways of attempting to recruit students and making faculty and advisers aware of their programs and undergraduate research opportunities. The most common is posting information on Web sites (88% of responding FSMLs), followed closely by posting printed advertising materials on their main campus (55%) or at other institutions (41%), and giving presentations to college classes (52%). Word of mouth from students who had positive experiences at a FSML was noted as being particularly effective at recruiting students. A small number of FSMLs reported using social networking sites for recruitment, and more informational tools are likely to appear as the utility of these sites becomes more apparent to FSMLs. The FSMLs that have a dedicated faculty or administrative academic coordinator position have a much greater ability to provide sustained and well targeted programs for undergraduates than do those that have to rely on the goodwill of FSML faculty members to run and manage their undergraduate programming.

Other challenges faced by FSMLs are neither new nor unique to FSMLs. They include ensuring relevance in curricular offerings, attracting rigorous and well-trained instructors, providing modern facilities for instructional and research activities, and obtaining adequate funding to accomplish their missions. Current concerns for many FSMLs as budgets tighten are their isolated location away from the main campus and their reliance on private funds. Despite these challenges, undergraduate education at FSMLs will remain a substantial part of the mission of many institutions, and thus will provide the next generation of scientists, conservationists, and others with opportunities to explore and gain a more thorough understanding of the natural world.

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