Specialization in Biological Sciences and Biomedical Research

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Abstract

In this paper, we discuss the growing specialization in the domain of biological sciences and biomedical research. Research and scholarship has grown so rapidly that the plural term "biological sciences" is often replacing the singular term "biology." The trend toward specialization is evident in the number of advanced degrees offered, in the subdivision of academic departments of biology into multiple units, and in the proliferation of life science departments across the university, including schools of agriculture, engineering, medicine and public health. In this paper we discuss the multiple origins of the field of biology as well as recent developments in the field of conservation biology.

Specialization and interdisciplinarity are often seen as opposite forces since, in some formulations, interdisciplinarity is intended to overcome the limits of disciplinary boundaries (Klein, 1990; Huutoniemi, 2015). But what if specialization and interdisciplinarity are both increasing? The fact that these two trends are occurring simultaneously might lead us to recast our understanding of interdisciplinarity.

In this paper we focus on the trend toward specialization in the biological sciences. This realm of scholarship represents an interesting case in its own right, but it is more than that. The biological and biomedical sciences collectively are the largest and best funded area of research, as well as the locus of many discussions regarding interdisciplinarity (for example, Massachusetts Institute of Technology, 2011). The first section is devoted to delineating the broad range of specializations that fall under the rubric of the biological sciences and bio-medical research. Evidence of the continued trend toward increasing specialization in this domain is also presented. The empirical focus is on the US, which remains the single largest source of programs and funding of research in this domain, but the scope and dynamism of the biological sciences in the US have implications for universities and research units throughout the world. The second section of this paper considers the relationship between the high and growing degree of specialization and discussions about interdisciplinarity. While specialization is incompatible with some interdisciplinary scenarios, it is entirely compatible with others.

We begin by reviewing the relationship between differentiation and scale. Following the propositions advanced by Blau (1970) and others, we maintain that, at a certain point, large scale endeavors make some degree of internal differentiation hard to avoid. However, we also argue for a more nuanced picture that takes scale into account but also identifies several other forces at work, namely: a) internal differentiation due to *intellectual subdivision*, b) *historical factors* that can have an enduring influence, c) the *gravitational pull* of large and powerful domains, and d) *exogenous factors*, primarily social and political, but also geographic. We outline the remarkable scope of the biological and biomedical sciences, which includes a discussion of intellectual subdivision and growth in the number of specialized degrees and academic journals. We then document the growing number of biology departments in the US as these have historically developed in schools of art and sciences. This is followed by a discussion of biological science departments located in other schools and divisions in the university. The case of conservation biology allows us to touch on some issues of differentiation outside the confines of academic departments. The chapter concludes with a discussion of the relationship between growing differentiation and specialization on the one hand and the growth of interest in interdisciplinarity on the other. We suggest that some overlap is a matter of semantics, while in other cases, the pattern suggests that interdisciplinarity will continue to coexist with growing specialization in the biological sciences and perhaps elsewhere in the research university as well.

Differentiation as a Function of Scale

The biological and biomedical sciences are a vast and multifaceted set of fields both in terms of research and instruction. The scope is so broad that some degree of internal differentiation would be predictable. Drawing on the influential ideas of Max Weber, Peter M. Blau (1970) elaborated the relationship between organizational size and internal differentiation based on an analysis of state employment security offices in the U.S. Specifically, he posits that “increasing size generates structural differentiation along various dimensions” (1970:204). In other words, the larger the organization, the greater the proliferation of departments or sub-divisions. Blau maintains that this will occur both horizontally (in terms of the number of units of similar type) and vertically (in terms of the number of layers in the organization). For our purposes we will focus on the horizontal dimension, specifically the quantity and features of degree programs and academic departments. Blau’s prediction is ultimately based on the value of a division of labor: "…subdivision of responsibilities occurs among functional divisions, enabling each one to concentrate on certain kinds of work (1970:203)." This division of labor reduces the cost of training, so that all employees do not have to learn every task undertaken by the organization. It also enables the organization to capitalize on the accumulated experience of individuals in each unit.

Blau's approach is intended to apply in a general way to formal organizations, but there are good reasons to expect that it will be particularly relevant in the academic context. Training costs are especially high with respect to learning the literature and techniques of particular disciplines. And keeping at the forefront, at the intellectual cutting edge, requires a great deal of time and energy. This is difficult enough to do well in one field but is even more challenging in multiple fields. Blau's own study of 115 colleges and universities in the US in 1968 reports support for the thesis that larger universities tend to have more departments (Blau, 1973).

In addition to the considerations on the faculty side of the equation, there are factors at work on the student side as well. A specialized degree may be more valuable in certain circumstances than general skills. Studies of college graduates suggest a premium in the labor market for those earning a degree in particular high-sought-after fields of study (Eide, Hilmer and Showalter, 2015). So there are reasons to expect an academic division of labor to emerge as a result of pressures related to both faculty as well as students.

The value of degree programs depends on their being recognized as valuable both by students and external audiences. This contributes to a pattern of "isomorphism," the tendency for organizational forms to resemble one another (DiMaggio and Powell, 1983). In other words, the value of specialized knowledge – say a degree in epidemiology – is enhanced if there is a large set of similar programs with similar requirements. This facilitates the recruitment of students and enables potential employers to understand the value of such a credential. Of course each program may choose to emphasize its distinctive qualities, but the forces pushing toward uniformity are powerful. As we will see, many patterns in the biological sciences are consistent with isomorphism between institutions, although there are also some notable exceptions.

Here we apply the logic of Blau's approach not to a single organization but rather to the broad domain of the biological sciences. As noted above, we suggest a number of complementary processes that account for the large number of units in the biological sciences, including historical factors – the degree to which biology was unable to consolidate its disparate components under a single academic roof. In terms of contemporary pressures, some of the growth of in specialization is likely due to internal differentiation, namely the subdivision of units as these become too large or too intellectually distinct.

A complementary force is the power of attraction that is represented by biology: it's intellectual success and extensive resources draw interest from researchers and scholars across academia. The result is the creation of hybrid fields around the borders of the biological sciences. We suggest that process can be this can be viewed as a kind of attraction somewhat akin to a gravitational pull that draws other domains toward biology. Finally, differences in orientation along political and applied dimensions can also contribute to differentiation among the biological sciences.

The (Very Big) Case of the Biological Sciences

The scale of bio-medical research makes it comparable to the GDP of many countries. Federal investments in biomedical research in the US reached $39.5 billion in 2017, with $32.4 billion concentrated at the National Institutes of Health. Just over half of federal investments in research are concentrated in the life sciences (National Science Foundation, 2016). While these sums are vast, the rate of increase has been slow over the last two decades, and leaders in the field are constantly concerned about maintaining a stable and growing funding base (for example, see Bluestone, Beier and Glimcher, 2018).

Government support for research, moreover, is only one part of the story. Private-sector research and development has far exceeded government funding for many years. Total US medical and health research and development spending was estimated to be $182.3 billion (Research America, 2018). Comparing US biomedical research to the economic activity of entire countries, this level of spending would rank it the fifty-second largest economy in the world, just behind Portugal and ahead of 160 other countries (United Nations 2019).

The scale of the biological sciences is also reflected in the number of research journals. The tremendous volume of research as reported in peer-reviewed scholarly journals is a fundamental indicator of the scope and dynamism of the field. In 2017, the ISI Journal Citation Reports included 2,438 journals categorized into 20 biological specialties domains. This represents an increase of 37 percent compared with 2002.[1] The number of journals is thus daunting, and the rate of increase suggests a powerful trend in the direction of differentiation.

Differentiation of Research Activity

Research activity over the years has been subdivided in many ways, such as basic research versus applied research or taxonomic divisions based on the study of people versus animals versus plants. One can also rank the unit of analysis from small– cellular and even nano-scale research – to larger units, such as the organism and even the ecosystem. However, many of these traditional methods of understanding divisions of the biological sciences are insufficient to capture the breadth of research activity, which fall along multiple dimensions simultaneously.

For example, in the biomedical sciences, some researchers work at the molecular scale to test medications in whole animal models as a preliminary trial prior to human use, while others use genetic assays to survey animal populations in order to understand their vulnerability to extinction. Some study fundamental processes such as aging at the cellular level in the hopes of developing cures for diseases related to human aging, while others investigate how to grow more nutritious food with fewer environmental consequences. Although scientists operating exploring this range of questions draw from a common pool of intellectual resources, the vast array of applications results in a considerable degree of specialization.

Differentiation of Degrees Awarded

The development of a specialized degree program reflects a serious commitment on the part of a college or university. Degrees represent a significant and enduring commitment of academic resources. The number of specialized degree programs offered in the biological sciences has been expanding over time. In 1960, the US Department of Education enumerated sixteen specialized degrees under the rubric of

[1] For a review of the limited coverage of the Journal Citation Reports, see Jacobs (2009).

biology (National Center for Education Statistics, 1960-2018). The latest (2017) report on degrees includes 85 specialized degrees within the biological and bio-medical sciences.

This increase in the number of degrees reflects in part the level of detail captured by the Department of Education listing. In other words, the number of degrees programs offered did not suddenly triple in number in 2006. Rather, the official list periodically catches up to the underlying growth in specialization. Other data sources, such as The College Blue Book (Cengage, 2018), capture the process of degree proliferation more closely by reporting on year-to-year changes in degree offerings in particular colleges and universities. Whatever the data source, the trend toward more specialized degree offerings is inescapable.

Differentiation of Academic Departments

Departments are a basic organizing unit in US colleges and universities. Departments are responsible for hiring new faculty members, and deciding on tenure and promotion, as well as organizing instruction. Departments structure intellectual and social life, along with academic norms and customs. Faculty find it difficult to start new departments, but once they are established, administrators find it difficult to close them.[2] The configuration of departments in the biological sciences is a complex story that is best approached via the diverse categories of institutions of higher education – liberal arts colleges, and large public and private research universities. As we will see, most fields – such as history, English, political science and sociology – have one department per institution, no matter the institutional setting.

In contrast, many large research universities have shifted from a single biology department to multiple departments. And the current set of departments often have hybrid names, suggesting a significant degree of internal differentiation. As we will see, there is not always (or perhaps not yet) a standard configuration that has replaced the old standard of a single-biology department. In other words, during this period of growth and change, the forces of standardization characterized as “institutional isomorphism” have not yet fully taken hold.

At major research universities, the presence of three or four biology departments based in a School of Arts and Science is common. Some still have a single biology department (e.g. New York University), while Harvard has five (not counting bio-engineering), as do the University of Minnesota and Ohio State University. Cornell University, on the other hand, has four biology-related departments within its College of Arts and Sciences: Chemistry and Chemical Biology, Ecology and Evolutionary Biology, Molecular Biology and Genetics, and Neurobiology and Behavior. These four academic units evidence complex trajectories of intellectual specialization both within individual departments as well as across them.

We note the variety of configurations of biology departments not as a criticism but rather as an exception to the general pattern of isomorphism found throughout US higher education. Most schools feature an English department, a history department, a mathematics department, and so on. While the emphasis in these fields may differ from school to school, the structure is generally uniform across institutions and quite persistent over time.

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[2] While departments are core units that cannot easily be opened or shuttered, research centers are far more flexible. Jacobs (2014) reports that each of the top 25 research universities in the US typically has more than 100 research centers in operation.

The Consolidation of Biology as a Discipline

We have thus far emphasized differentiation as an explanation for the multiplicity of life-science departments, but this approach assumes that a single biology department was a natural or even inevitable starting point. A brief examination of how biology became a standard feature of American colleges and universities will alter this view. In fact, biology as a field initially had difficulty in consolidating disparate groups based in distinct domains of naturalist inquiry. The establishment within major research universities of biologically based departments in disparate schools – medicine, agriculture, public health, veterinary medicine, nursing and public health – continues to reflect these unsettled 19th century organizational debates.

Most histories of biology focus on intellectual developments and pay little if any attention to the organizational context in which biological research is being conducted (eg., Mayr, 1982). An exception is the history of scientific tools and techniques biologists used for their research (Clarke and Fujimura, 1992). Fortunately, several valuable historical accounts help to explain how biology became ensconced as a discipline in the context of US universities despite the presence of a number of obstacles in the way.

Toby Appel (1988) documents the emergence of multiple biological societies in the late 19th century. She stresses the organizational disarray of biology in this formative period, 1883-1923. The American Society of Naturalists 1883 was founded as an effort to bring biologists together in one organization, but this effort was countered by the establishment of a number of more specialized organizations. Specifically, the American Physiological Society, the American Association of Anatomists, the American Morphological Society, the American Psychological Association, the Botanical Society of America and a number of other organizations splintered the membership of the nascent ASN and made it more difficult to claim biology as a unified field. Within AAAS (the American Academy for the Advancement of Science), biology was divided into botany and zoology, each with its own section. The Union of American Biological Societies, founded in 1923, served as a federation of independent scholarly societies rather than a single, unified disciplinary association. Appel concludes that biology in this period could not claim to be an intellectually coherent discipline, especially in terms of comparison with the field of chemistry.

In this context, it is curious that universities had begun to rapidly establish biology as a standard academic department. The puzzle deepens when the contrast with the German arrangement is noted. In Germany, biological studies were divided into five departments: anatomy, botany, pathology, physiology and zoology (Pauly, 2000, p. 139). Given then influence of the German model on the emerging scientific university model being developed at Johns Hopkins, Harvard, Chicago and elsewhere, how were these disparate fields consolidated in a single department of biology? Pauly suggests that the impetus was largely from university presidents who sought to divide the world of scholarship into a manageable number of departments. In other words, organizational considerations rather than intellectual coherence appeared to have played a prominent role. As the classical and religious orientation of the pre-civil war university gave way to a specialized and scientific orientation, by the early 20th century biology departments took their place alongside philosophy, history, economics and other domains of inquiry.
A common organization, however, did not settle many questions regarding the content of instruction. Some sought to orient the newly-established biology department as preparatory training for medical school; in other words, a "pre-med" track. Others viewed biology as the nascent research-based science that would supplant amateur naturalism in the modern university.

Another important development for biology outlined by Pauly was the establishment of biology as a standard course for high school students. The pattern, first initiated in New York City with assistance from

Columbia University biologists, would be that all high school graduates would typically have exposure to biology in high school, which they could pursue further with a college major and subsequently enter graduate training in either research or as a physician or surgeon. The interconnections with other levels of education would thus serve to make biology as part of an interlocking sequence of instruction.

Biological Sciences Across the University

Thus far our discussion of departments has noted the division of the biological sciences within the “arts and sciences” component of the research university. While the presence of three or four biologically-related departments is notable, this actually represents only a small portion of biological research and teaching in the contemporary American research university. While the arts and sciences may represent the historical core of research universities, in today’s university context, the professional schools are often larger in terms of enrollment and research activity.

Medical schools represent another institutional setting for the biological sciences. Research and teaching in this area is typically referred to as “biomedical research.” Fewer than 50% of the 400 American research universities have medical schools; among those that do, a large set of additional biomedical departments can be found.[3] It is typically for medical schools to feature eight or more basic departments and about a dozen clinical departments. In the US, bioethics has typically been organized a center rather than a department. Roughly 100 institutes or centers but only 10 departments have been established in this area (Bioethics.net, 2019).[4]

Schools of agricultural sciences date back to the Presidency of Abraham Lincoln in 1862 when the US Congress approved the Morrill Act. Approximately 75 colleges and universities, including prominent institutions such as Cornell University, Ohio State University, and the University of Wisconsin, continue to feature agricultural research. Schools of agricultural science typically are divided into about ten departments. The thirty schools of veterinary medicine add yet another set of applied biological science programs.

Other professional programs show high rates of hybridization and differentiation as well. Fifty-nine US universities feature schools of public health.[5] The set of departments in public health schools – six appears to be the modal number of departments -- typically include biostatistics, environmental science, epidemiology, and health policy and management department. Biology has also established a beach-head in engineering schools, which routinely feature bio-engineering departments. Schools of nursing represent yet another locus of applied biomedical teaching and research on campus.

The large scope and tremendous breadth of the biological sciences makes a degree of specialization inevitable. The particular organizational form this takes in US research universities reflects the historical configuration of colleges and research universities. While liberal arts colleges typically endeavor to cover as much biology as possible within the confines of a single department, the number of biological and biology-related departments can quite high in universities that have schools of engineering, medicine,

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[3] This estimate is based on the 2019 Carnegie Classification of Institutions of Higher Education and the 2018 US News and World Report ranking of medical schools.

[4] A complete catalog of bio-medical education would include a discussion of the 142 schools of pharmacy (American Association of Colleges of Pharmacy, 2019).

[5] A valuable source for the history of public health is the 2003 Institute of Medicine report (Gebbie, Rosenstock, Hernandez, 2003).

veterinary medicine, dentistry, nursing, public health and agricultural sciences. For example, the University of Chicago lists 10 basic and 13 clinical (medical) departments in its Division of Biological Sciences.

Large state universities often have sufficient numbers of students to host a particularly large number of programs. Michigan State University, for example, has some 40 biology and biologically-related departments: 5 in its School of Arts and Sciences; 10 more in its School of Agriculture; 15 (7 basic, 8 clinical) in its School of Medicine, 7 more in the school of Veterinary Medicine, plus one in engineering and two in nursing. This list does not include 9 specialized degree programs in Dentistry.

Departments are thus a key unit of analysis. The clear trend in the field of biology is an increase in the number of units, the number of domains in that have achieve the status of a department. As firmly rooted parts of the university structure, academic departments do not come and go often but have great staying power. And new departments are still being born.

Exogenous Factors in the Case of Conservation Biology

The case of conservation biology enables us to add a layer of complexity to this picture. Thus far we have focused on departments as a key organizational unit, but in any particular historical case various idiosyncratic and external factors are likely to play an important role.

The Ecological Society of America (ESA), which has recently celebrated its centennial, is the national organization for academic ecologists in the US (Ecological Society of America, 2019). ESA performs many of the same functions as other academic societies: it organizes an annual meeting, publishes scholarly journals, and represents the field to external audiences. ESA members can join one or more of the 32 sections which range from the Agroecology to Environmental Justice to Paleoecology.

Exogenous factors, ranging from contemporary political contexts to the US tax code have left their mark on ecology. The ESA differs from many other scholar societies in that it has faced a series of debates over the years regarding the tension between an orientation toward basic research on ecosystems on the one hand and the demand for action to protect or restore endangered ecosystems on the other. This tension in part reflected concern about the US tax code which limits political or social advocacy on the part of non-profit academic organizations. The result was the emergence of competitor organizations such as the Ecologists Union (1946-1960) and, more recently, the Society for Conversation Biology, founded in 1985 (Nyssa in press).

We think it is best to understand conservation biology as a field that is still struggling to find the organizational structure that would offer academic legitimacy, including the opportunity to train both professional conservationists and the next generation of academic leaders, all while trying to address the urgent challenges posed by global species extinctions. While conservation biology has been increasing rapidly (Meine, Soulé & Noss. 2006; Bakker et al., 2010), leaders in the field remain concerned that the field is not suited to cope with the magnitude of the world-wide species catastrophe confronting our planet (United Nations Environment Program, 2012).

Organizationally, conservation biology has had diverse roots, exemplifying the role of other exogenous factors such as agricultural extension programs to support regional economies. Some programs remain based in schools of agriculture or natural resources, but in that context they usually garnered fewer resources than in departments that emphasized sciences related to crop yields. Newer conservation biology programs are often strategically located in ecology departments in the school of sciences (or arts and sciences) (Nyssa 2014).

In addition to the influence of national politics or regional economies, the organization of conservation biology exhibits geographical clustering that reflects the continued importance of local field sites and test plots for conservation research. For example, coastal schools such the University of Maine and Oregon State University are more likely to feature marine biology programs than are universities in land-locked states; the Marine Biology Web (2019) lists 55 such programs. \Indeed, with only two exceptions, all of the marine biology programs are located in coastal states. Conversely, rangeland management programs are concentrated in the interior states, specifically from Texas Tech University to South Dakota State University. A total of eleven such programs are listed by the Society for Rangeland Management (2019).

In terms of university location, conservation biology programs are rarely departments *per se* but rather take the form of "programs." These reside both above and below the department level and everything in between. These programs, regardless of administrative structure, or "home," are at the intellectual and educational interstices of the traditional departments. This organizational variety could be highlighted as one of the things pushing the field toward interdisciplinarity. But the sheer complexity of ecological phenomena pushes these programs simultaneously toward increasing specialization. So, as we will discuss in greater detail below, this pattern can be seen as both specialization and interdisciplinarity.

Reconsidering Differentiation and Interdisciplinarity

The evidence presented above suggests that the biological sciences, as organized in the US, are internally differentiated. The number of journals – numbering in the thousands -- is large and growing. The number of specialized degree fields within biology – currently at 85 – is large relative to most disciplines and has been increasing over time. And there are multiple academic departments that focus on biological and biomedical topics– within schools of art and sciences, as well as across other major schools within the research university.

Some criticize disciplines as a traditional, hide-bound 19th century or 20th century formulation that is out of step with current research needs. The case of the biological sciences poses two problems for this view. First, biology has been and continues to be incredibly successful while being organized into a myriad of specialized degrees, departments and programs. Second, differentiation in the biomedical sphere continues apace. While its 19th century roots remain visible, differentiation is not simply a holdover from the past but is an ongoing process that continues to spin off new journals, new degrees, new departments and new programs.

While specialization is unrelenting, there can be little doubt that interdisciplinary activity also has grown in recent years. The presence of interdisciplinary programs is often cited as a selling point on university websites. More students are now graduating with interdisciplinary degrees – many in social sciences and humanities. (Jacobs, 2014).[6] And more schools feature interdisciplinary programs and research centers (Brint, et al., 2009). In terms of scholarship, studies show that the number of co-authorships have

[6] Team-taught classes and cross-listed classes have been quite high for a quite some time with no clear time trend always quite high, no clear trend (Jacobs, 2014).

increased over time (Wuchty, Jones and Uzzi, 2009). Interdisciplinary citations have also increased but mostly in "intellectually adjacent" areas (Porter and Rafols, 2009).

How can we reconcile a growing interest in and commitment to interdisciplinarity with increased number of departments and increased specialization especially at the level of graduate training?

We would like to suggest that in some cases, they are the same thing! For example, the creation of the field of bio-statistics at the intersection of biology and statistics can be viewed by as the growth of an interdisciplinary field, and perhaps from the point of view of the MIT White Paper as an instance of "intellectual convergence" within the natural sciences. Yet the creation of a separate bio-statistics department, often in schools of public health or in medical schools, but sometimes in schools or arts and sciences, can be viewed as yet another case of differentiation.

Bio-statistics represents the growth of a new area of statistics as it pertains to biology that is so large as to warrant its own department. So too the field of bioengineering. While some observers may claim that the creation of a bioengineering department represents a convergence of biology and engineering, we maintain that it is more realistic to view it as another case of differentiation. The existence of bioengineering does not result in the infusion of biology into most other engineering spheres.

Differentiation can be seen as blended with the "gravitational pull" of the biomedical sphere. The very size, resources and dynamism of the bio-medical sciences inevitably draw in intellectual contributions from other parts of the academic system. We suggest that this process can be likened to a gravitational field. The intellectual (and perhaps financial) pull of biology and biomedical research draws in and helps to create new fields in engineering, chemistry, physics, statistics, ethics, and public health. Bioengineering, bioethics, biophysics, and biostatistics are the clearest examples of this pattern.

This particular trend toward specialization need not be viewed as incompatible or inconsistent with growth of interdisciplinarity. Rather, it is consistent with the notion of "specialized interdisciplinarity" used by Jacobs 2014. As we have seen, the historical origins of biology as an academic department can be viewed as running this process in reverse. Disparate fields were brought together in an uneasy alliance under the rubric of scientific biology. Thus, connections that would be seen as interdisciplinarity among the five German variants of biology would be seen as intra-disciplinary conversations in the American context.

The more fundamental point is that the nature of interdisciplinarity depends where the boundary lines between fields are drawn. In the case of ecology, the field emerged in no small part because of the joining of two existing fields: botany and zoology. Thus, collaborative work between botanists and zoologists was at one time considered interdisciplinary. If both scholars are located in ecology departments, with one specializing in botany and the other in zoology, would this collaboration still be considered interdisciplinary, or would it simply be regarding as spanning specialties within a single field? We propose the following interdisciplinary paradox: the more specialized the degrees offerings, the more numerous the departments, the more scholarship becomes eligible for the "interdisciplinary" label.

Particularly problematic from the point of view of interdisciplinarity is the growing internal differentiation within fields. This is responsible for the separation of ecology, evolution, cellular, molecular biology in basic biological science departments. Neuroscience is another case of internal differentiation, usually branching off from the biological wing of the psychology department. Jacobs (2014) suggests that the ability of a field to define a broad intellectual domain enables it to become established as a standard feature of a modern university. Thus, fields such as history, economics and mathematics are broad areas of knowledge and scholarship without rigidly defined boundaries. These properties underpin the presence of academic departments representing these fields in most colleges and universities in the US.

The growth in size of the biological sciences, more in terms of research funding than in terms of student enrollments, enables internal units to break away to form own fields. While academic disciplines typically have many internal divisions and areas of specialization, it is only under special circumstances that these divisions are recognized as warranting separate degrees; the creation of separate departments is even more exceptional.

The biological sciences share many common tools, techniques, and ideas. Some (e.g., Milgram, 2018) have suggested that academic specialization results in an inability to comprehend the work of researchers and scholars in other fields. We do not believe that this criticism applies in the case of the biological sciences. Within the broad domain of biology, most scientists would find themselves in agreement regarding core ideas – structure of DNA, the importance of natural selection, etc. Ecologists who focus on the operation of ecosystems do not hesitate to use genetic markers in their research (Allan and Max, 2010). In the case of the biological sciences, it is not a debate over key concepts that produces differentiation but rather the very success of the biological research paradigms. The growth of specialized knowledge, and the ability of biological scientists to garner support for their research, results in institutional differentiation.[7]

Returning to the case of conservation biology, the organizational structure of the field may be viewed in different ways. Some may view the location of conservation biology programs in interdisciplinary programs and research centers as emblematic of the success of contemporary interdisciplinary, and as an example that other fields should try to emulate. On the other hand, we suggest that the lack of its own department and the inconsistent placement of conservation biology in various units across the university has tended to impede the development of this field. In other words, having strong conservation biology departments or schools, as is the case with public health, would strengthen the position of conservation biology in the academy.

In the terms used by organizational sociologists, a clear organizational context for conservation would contribute to the internal and external legitimacy of this field. Some of same goals could be accomplished with stronger partnership between conservation biology and other approaches to ecology within departments of ecology. In other words, specialization plus interdisciplinarity might be a beneficial organizational structure within universities in terms of raw resources (i.e. getting the "best of both worlds" with these programs that float in between departments) but it comes, as always, with costs—to intellectual coherence, political leverage, post-degree placement rates, and other desirable benefits of organizations. External resources would help to bolster the case for a department and help to generate models of conservation interventions that could be replicated (scaled up) across the many ecosystems that are facing grave and urgent threats.

[7] Organizationally speaking, one of the easiest ways to accommodate interdisciplinarity is via the creation of research centers. Jacobs (2014) notes that large research universities in the US are populated with many such centers.

The case of the biological sciences suggests that the issue of how best to organize science will not be settled easily or soon. Specialization continues to be a powerful force in shaping the organization of this diverse set of fields, with multiple historical and contemporary factors at work in addition to sheer scale.

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