The Natural Sciences in the University: Change and Variation over the 20th Century

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The changing academic priorities of universities are often discussed but little investigated by social scientists: What accounts for the striking expansions and contractions in disciplinary fields over time? Focusing specifically on the natural sciences, this article articulates a global-institutional argument that holds that deep shifts in ontological conceptions of action and structure over the course of the 20th century fomented shifts in the teaching and research emphases of universities worldwide. Specifically, it hypothesizes that scientific fields that are premised on fixed categories and hierarchies of entities (for example, zoology) declined relative to fields that are premised on dynamic, horizontal networks of entities (for example, physics). In addition, it hypothesizes that as globally institutionalized reality shifted in favor of human, rather than divine, actorhood, fields that position their practitioners as active investigators in a dynamic universe gained ascendance over those that position practitioners as passive observers of a divinely ordered universe. Using data on worldwide faculty composition from 1915 to 1995, the authors found that these shifts indeed transpired—the fixed-categorical fields of astronomy, botany, and zoology declined precipitously, while the dynamic-network fields of geology, biology, chemistry, physics, and mathematics performed much more robustly.

In recent years, a sense of crisis has permeated the public discourse on higher education (Bloom 1987; Hirsch 1987; Readings 1996; Shils 1982). Central to the discourse has been the sense that university teaching and research are corroding. Disciplinary fields in the traditional liberal arts core, such as classics and foreign languages, have fallen from prominence, to be replaced by the mundane and solipsistic—including business, communications, and other job-training, personal-identity, and vague multidisciplinary pursuits (Brint 2002). The result, it has been said, is a university system that is in ruins (Readings 1996).

In spite of the hand-wringing, systematic data on long-term changes in the university’s academic composition are rarely presented or analyzed in the literature (Gumport and Snydman 2002). In the sociological subfields where one may look for information, there has been little. Most obviously in the sociology of education, the composition of university teaching and research has been mostly unrecognized as a legitimate topic of study; the subfield instead has focused on the hidden agendas of
power and privilege that are alleged to permeate school subjects (Apple 1990; Popkewitz 1987). For its part, the sociology of science has focused on the individuals and groups who use and deploy knowledge much more than on the content and structure of the knowledge system itself (Knorr-Cetina 1999; Latour 1986; Merton 1973). Sociologists of knowledge, meanwhile, have focused on the system level and have helpfully illustrated the role of social forces in the ordering of the knowledge system, but they have tended to privilege the power interests of groups of actors, rather than to consider the bases of broad, deep change in the fundamental nature of the knowledge system (Riggs 1992; Swidler and Arditi 1994). Historians of science have further illustrated the socially constructed nature of scientific “truth,” but the field has tended to produce fine-grained studies, rather than large-scale, long-term accounts (Nye 2003; Olby et al. 1990).

The broad explanations of compositional change that do exist have emphasized two levels of the institutional environment. The first, and the most commonly discussed, is that provided by the university itself (Altbach 1998; Clark 2002; Slaughter and Leslie 1997). Features of the university, especially the demographic characteristics of students and funding sources, have frequently been linked to change and variation in academic priorities. Beyond the university environment, features of the nation-state have been associated with variations in the university’s composition (Dierkes 2001; Haraway 1989; Wong 2004). The conduct of national wars, the type of national government, and the nature of colonial experience have all been linked to the relative fates of various disciplines in the university.

Empirical support for university- and nation-state-level arguments has been limited but nonetheless consistent: Both environments appear to provide building materials for university studies. But recent work in sociology has suggested that teaching and research emphases arise, at least in part, from another level of the institutional environment, one that has less often been considered by social scientists—the global-institutional environment.

Global institutions, to be clear, are authorized and legitimated definitions and assumptions, taken for granted in world cultural scripts and organizational rules (Meyer, Boli, and Thomas 1987). Global institutions appear as universalized “facts,” often of a scientific variety (Drori et al. 2003; Wallerstein 1991); as naturalized “laws,” such as those underlying human rights (Ramirez and McEneaney 1997; Tsutsui and Wotipka 2002); and as generalized principles, typically purveyed by consultants and other professionals (Meyer et al. 1997). They are the master elements in a culture’s periodic table; they are reality’s constitutional documents. Here, we focus on changes in the broadest features of the global-institutional frame. Globally institutionalized cosmologies, specifically, provide the narrative forms whereby the units and features of reality are believed to come into existence. Cosmologies, in turn, lay the groundwork for globally institutionalized ontologies, which establish the nature of “action” and “structure” in the everyday world.1

Schematically, we argue that long-term shifts in the globally institutionalized cosmology produce subsequent shifts in the globally institutionalized ontology—that is, in action and structure. These shifts change the content and quality of world-level “reality” and thus reconstitute the building blocks with which universities are made. The result is recomposition in the body of teaching and research across domains of knowledge and throughout the world.

The argument draws broadly on sociological institutionalism and involves four main assertions. The first is that an institutional frame shapes the university’s elemental building blocks. If the distinctive task of the university “is the methodical discovery and the teaching of truths about serious and important things,” and if what is “true” and “serious” and “important” are not spontaneous facts but, rather, cultural and organizational accomplishments, then changes in the institutional frame should produce changes in university activities (Shils 1982). One is less likely to find a department of theology, for example, if the cosmology designates no God. There must be a there there for university studies to occur.

The second assertion is that it is not just any institutional frame but, rather, the global one that channels the main constitutional matters into university teaching and research. Global
institutions take priority over local and national ones. First, this global preference is due to the founding universalism of the university itself. Even at its genesis in medieval times, the university adopted the most general posture, using a universal language (Latin) to educate a pan-European student body in universalistic forms of knowledge (i.e., reason and later science) (Altbach 1998). Accordingly today, an education from the University of Liberia should “not only enable [graduates] to assure the future growth and development of Liberia but make it possible for them to contribute to the world at large” (University of Liberia 1967). Second, the priority of global institutions vis-à-vis universities is due to the universalism that is inherent in contemporary models of national state and society: To be a “nation-state” is to have and sponsor a “world-class university,” meaning one that conforms to global standards (Meyer et al. 1997; Riddle 1993). Third, the preponderance of the global-institutional frame is due to recent increases in globalization itself—the sense that the world is one, whole, interconnected entity. On economic (Chase-Dunn 1998), political (Rosenau and Czempiel 1992), and cultural (Boli and Thomas 1999) grounds, the “globality” of the world is clearly intensifying, thereby widening the global streams that feed into university pools (Robertson 1992). In the natural sciences, in particular, national borders are increasingly being crossed for publications and conferences; advances in communications have been instrumental in this development (Basu and Kumar 2000; Narváez-Bertheleme 2002; Rowe 2003). For all these reasons, we expect global institutions to be preponderant.

Our argument’s third main assertion is that the global-institutional frame’s models of action and structure provide, in Foucault’s (1994:xii) terms, “the basis or archaeological system” that is common to all the university’s knowledge domains and organizational levels. These root ontological features lie at the heart of imagined reality and thus simultaneously establish foundations on which the humanities and the natural sciences rest, including all their disciplinary fields and the subject matters within them (Frank and Gabler forthcoming).  

Finally, the fourth assertion of our argument lays out the causal pathway—from a changed theory of origins to a changed theory of being (action and structure) to a reconstructed university. The directionality is both logical and historical, although it is by no means unidirectional. To some extent, of course, university professors engage in the articulation of reality, feeding materials back into the cosmology and ontology. Typically, however, such contributions are incremental, fulfilling and elaborating the global frame more often than fundamentally revising it.

The mechanisms that link global institutions to universities around the world are many—educational and disciplinary associations, students’ demands and enrollment, and funders’ support. We believe that these mechanisms follow, broadly at least, the globally institutionalized scripts that we treat as primary.

In short, we argue that the global-institutional frame establishes the broad conditions of reality and thus plays a crucial role in constituting the teaching and research emphases of universities. This argument departs from orthodox views in three decisive ways. First, we treat the motor of university change as cultural or institutional. This does not mean that economic or political processes have no bearing on the composition of activities, only that they operate in tandem with institutional ones. Second, we treat the reconstruction of the university as a global process. This does not mean that national- and university-level environments are inconsequential to university priorities, only that they have effects alongside global ones.  

And third, we treat changes across the university’s branches and fields as having common denominators in action and structure. This does not mean that there are no particular branch- or field-level pressures on academic menus (e.g., from the job market, funding streams, or accidents of discovery), only that they operate within the context of institutional processes that overarch knowledge domains. Thus we make our central case: Shifts in the global-institutional frame underlie changes in the composition of university activities.
THE NATURAL SCIENCES

Background
As the cosmology shifted over the modern period from a story of sacred creation to a story of mundane evolution, it prompted movements in core features of the globally institutionalized ontology. Revised action templates extended human control into new territories, both general and specific to knowledge (Meyer and Jepperson 2000). And revised structure templates reshaped vertical hierarchies into horizontal assemblies and fixed categories into dynamic networks. The root models of “reality” changed.

Disciplines that were relatively inconsistent with the new global-institutional frame suffered throughout the university. Although the natural sciences as a whole are typically presumed to be the very embodiment of the contemporary worldview, we suggest that the so-called basic natural sciences are more similar in their fundamental assumptions about the universe to the receding humanities than is commonly assumed. Correspondingly, we expect to see a decline in the share of the university devoted to these disciplines—particularly in those that are most tied to the outdated blueprints of action and structure.

Classical and medieval cosmology viewed the world in the manner of an Aristotelian hierarchy, created and motivated by God, from base materials, such as rocks, up through plants and lower animals to man (with room below for lower orders of man, such as women and slaves) and continuing beyond common men to great men, such as priests and rulers; then to angels and other divine beings; and, finally, to God Himself. Both the humanities and the basic natural sciences came into being as intellectual tools for the investigation of this hierarchy; the social sciences (and the more applied natural sciences), by contrast, are of relatively recent vintage and embody different assumptions (Frank and Gabler forthcoming).

The humanities are charged with the study of the top of this hierarchy—God; other divine creatures; and higher men, such as philosophers and artists. The fundamental premise of the humanities is that there are Great Works and Great Men, superior in merit, exemplary in accomplishment, and revelatory in insight—beyond the reach of average individuals. For example, theologians read the Bible, philosophers read Aristotle, and scholars of literature read Dante—all with the presumption that these works are uniquely important and telling of the human condition. (The social sciences, by contrast, would regard these documents as merely products of a particular time and place—at best, reflective of the conditions in which they were produced.) This is a view of the classical hierarchy from the top down.

The basic natural sciences also arose to study this hierarchy, but from the bottom up. By rigorously observing and categorizing the incidence and behavior of mundane phenomena, such as rocks, ferns, and fish, natural scientists might hope gradually to reveal the universe in all its divine order. Although the view of the hierarchy looks different from the bottom than it does from the top and necessitates a different methodology, in both directions the ultimate object is the same: to map a picture of a static, rigidly ordered creation so as to gain a better understanding of our place in it.

In her historical study of primary school science textbooks, McEneaney (2000) captured this aspect of the scientific enterprise. On the basis of a multinational sample of textbooks, McEneaney concluded that “before World War I, science was depicted as fact-oriented and taxonomic rather than broadly processual. . . .” Commonly, the textbooks march through a panoply of local species of flora and fauna, with fairly regular sketches and an occasional photograph of the species under study” (p. 6). The enterprise was framed as almost theological: “The depicted science involved a kind of filling-in-the-blanks in a god-given taxonomy. In this sense, expertise is located in the deity, and his work is merely revealed to human practitioners of science” (pp. 18–19).

Ultimately, however, McEneaney found—consistent with our argument—a fundamental shift in the global-institutional frame over the course of the 20th century. Whereas early in the century (and before), science was about discovering the world as God had created it and thus doing tribute to His genius, science today is about empowered individual actors manipulating a dynamic, horizontal universe. McEneaney found this dramatic shift manifest
in a newfound emphasis on a child’s interests as the drivers and virtually sole justification of his or her scientific activities:

Primary school science (as embodied in textbooks) has transformed from an inert body of facts to principles for action and participation by individuals. In short, the main pedagogical imperative of contemporary primary science is both to cultivate agency in students and to construct a cultural field in which students believe they can exercise this agency.” (McEneaney 2000:16)5

To recap, there has been a redefinition of action and structure. Actorhood has been relocated increasingly from God down through professional scientists and ultimately to all individuals, even young children (Gabler 2004). Instead of passively observing a universe that was created at Genesis and thusly ordered forevermore, individuals are now active participants in a dynamic universe (Drori et al. 2003; McEneaney 2000). Structure is no longer conceived as a static vertical hierarchy but, rather, as a dynamic horizontal system, unified in shared processes, rather than in a divine order. These shifts, combined, have led to a model of “reality” that is consistent with the idea of humans actively manipulating their natural environment. This is not to say that God has been excommunicated from the institutionalized ontology; rather, the mark of His (much-depersonalized) hand is seen in low-level processes as opposed to high-level taxonomies. This change makes it legitimate for humans to reorder the visible universe; the processes, rather than the manifestations, are taken to be the ultimate level of reality. We should expect that those disciplines that are more consistent with the altered global-institutional frame should retain a greater share of universities’ finite resources than should those that are not.

We restrict our discussion here to what are usually termed the “basic” natural sciences—that is, those natural sciences that do not have inherent practical applications (although, as noted, their findings may well be used in an applied context). These disciplines include astronomy, biology, botany, chemistry, geology, mathematics, physics, and zoology. We chose these eight disciplines to include here both because of their substantive similarity—all involve the investigation of the natural world with no a priori premise of application to technology—and because they are, by common practice, grouped together in university faculties as well as in sociological and historical accounts. Three of these disciplines—astronomy, botany, and zoology—are definitionally tied to the outmoded global-institutional frame. Four of them—biology, chemistry, physics, and geology—are relatively adaptable to ascendant blueprints of action and structure, but the final one—mathematics—is uniquely suited to the contemporary worldview. We expect these disciplines’ fates to have diverged accordingly over the course of the 20th century.

**Disciplines Expected to Experience Relative Declines**

Astronomy, botany, and zoology are all fundamentally premised upon the observation and classification of discrete, static fields of phenomena. They assume, in other words, a “reality” that is structured around fixed categories and vertical hierarchies in which the capacity for action is restricted largely to the external spiritual realms. “Naturalists who laid flora and fauna away in specimen cabinets and astronomers who recorded the positions of the stars and planets were accumulating a factual variorum of the Creator’s imprint on the universe” (Kevles 1971:7).

Among the three disciplines, astronomy is the very paradigm of the observational science. Although we have sent men to the moon and robots to Mars, for all practical purposes astronomical phenomena are completely removed from human contact—we can do no better than to gaze at the stars and to map their movements. Among the natural sciences, astronomy is perhaps uniquely close to the humanities, with ties to classic works in art and philosophy. Although this orientation has earned astronomy an esteemed position within the university and unique “marquee value” in popular culture at large, we do not expect that this success in the popular imagination will translate into academic emphases. Astronomy’s vision of the cosmos is just that—a vision. Human astronomers look passively out at the

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5. Italics added for emphasis.
wonders of God's creation. This vision is manifestly inconsistent with an emphasis upon empowered individuals effecting change in a dynamic universe. As the gulf between “the heavens” and “the earth” evaporates, the justification for the discipline of astronomy erodes. Substantively, in fact, astronomy has nearly become a branch of physics (Rosner 2002:197); the field keeps its distinct identity largely on the basis of historical momentum. Thus, while we would not expect any members of a university community to deny the symbolic value of the astronomical enterprise, we expect that, over the long run, astronomy's share of universities' teaching and research resources will have declined.

Botany is a similarly classificatory science—indeed, Enlightenment astronomer William Herschel saw himself as a “celestial botanist” (Smith 2003:160). Like all fields, botany has moved to incorporate redefined models of action and structure; the Botanical Society of America (BSA) now highlights the processual aspects of the field and the crucial impacts of human action. Botanists, the BSA's web site notes, may “study interactions of plants with other organisms and the environment... Botanists study processes that occur on a time scale ranging from fractions of a second in individual cells to those that unfold over eons of evolutionary time.” Nonetheless, the field's identity—unlike that of biology—is fundamentally tied to its observatory and classificatory origins. The discipline's seminal founders included Gaspard Bauhin and Carolus Linnaeus, each of whom meticulously observed and classified thousands of plants. Modern botanists produce and refer to vast encyclopedias of leaf shapes and root systems. A frankly defensive document published by the BSA explicitly argued for the value of a comprehensive understanding of the plant kingdom, as opposed to the “narrow training” of biologists. Thus, the continued health of the field of botany is contingent upon the persistence of the notion that an understanding of universal processes is inferior to detailed knowledge of specific plant species. We expect that as the global-institutional frame moves toward process and away from the discrete, static morphologies on which the discipline of botany was founded, there will be a relative decline in the priority accorded to botany.

Finally, zoology is botany's analogue in the animal kingdom. The very fact that botany and zoology are discrete fields is a sign of their link to the outmoded cosmology, with its notion of static, hierarchical “kingdoms” as opposed to evolving and integrated systems. While biologists conceive of life as a fundamentally unified process that cannot always be readily classified into one “kingdom” or another, zoologists and botanists maintain their traditional boundaries (with the occasional border dispute over such organisms as bacteria, algae, and fungi). As botanists devote themselves to the observation and cataloging of plants, zoologists map the diversity of animal life. Zoology courses that are offered at the University of Toronto include Introductory Animal Physiology, Field Ornithology, and Comparative Endocrinology of Invertebrates. Although zoology, like botany, has recently begun to position itself as a dynamic, process-based science, it finds itself in a similar quandary—the more it emphasizes ecology and the universal processes of life, the more it calls into question the validity of its own existence as a field. Historically, zoology and biology have been separated by a profound theoretical rift; many prominent zoologists went to extensive (though ultimately futile) efforts to prevent biology from emerging as the authority on the nature and workings of evolution (Mayr and Provine 1998). It is telling in this respect that the University of Toronto's zoology courses include a number of courses that explicitly invoke biology (Developmental Biology I, Biology of Fishes, and Biology of Mammals). The zoological cosmology—entailing a rigid hierarchy of species created by God and observed (but not manipulated) by human beings—has lost legitimacy to the newly dynamic institutionalized worldview, in which humans are an integral and active part of an ever-changing natural ecology. Thus, we expect that zoology will have lost relative standing in the university over the course of the 20th century.

**Disciplines Expected to Experience Relative Persistence**

Biology, chemistry, physics, and geology—like astronomy, botany, and zoology—are fundamentally about the observation and under-
standing of the fundamental workings of the universe. They differ from the latter group of disciplines, however, with respect to their assumptions regarding both actorhood and structure. The latter group of disciplines presumes that their practitioners are passive observers of a fixed, categorical, hierarchical universe; the former group, in contrast, presumes a practitioner who is an active experimenter, discerning the nature of dynamic processes that are common across what were formerly construed as rigid existential orders (as in the “animal kingdom” and the “plant kingdom”). Although such disciplines as medicine and engineering are premised upon an even-more-active (indeed, intervening) practitioner, the disciplines of biology, chemistry, physics, and geology are all—relative to astronomy, botany, and zoology—relatively amenable to the process-oriented, human-centric model of nature that is currently institutionalized throughout the world. Therefore, we expect that all four of these disciplines will have demonstrated greater persistence throughout the 20th century than the disciplines discussed earlier.

Geology may seem to be more appropriately grouped with the fundamentally classificatory sciences. Indeed, we expect geology’s footprint in the university to have shrunk over the course of the 20th century, although not as precipitously as that of astronomy, botany, and zoology. Although the typical individual’s experience with geology probably involves a lot of rock classification, geology has long assumed a world in which humans are sovereign actors—drilling for oil, say, and mining for gold. Furthermore, the discipline has always been deeply concerned with the ongoing processes that shape the Earth. Although plate tectonics is a relatively recent development in the field—formulated only in the 1960s—geology has long operated with a hybrid model of structure: fixed-categorical (i.e., types of rocks) as well as dynamic-network (i.e., the physical development of the Earth). Geology’s founders, from Herodotus on down, have concerned themselves not simply with the classification of earth phenomena, but with ongoing processes from silt deposition to fossil formation. As the globally institutionalized frame has recast our planet as a dynamic system, geology has been well positioned to be the disciplinary location for studies of the newly conceived “ecosystem.” The field has developed close relationships with other “earth sciences,” such as geophysics and oceanic science, as well as with the social science geography. Such within-field changes, as we noted earlier, are also to be observed in departments of botany and zoology—and like these classificatory sciences, we expect geology to have lost ground to lower-level sciences, such as physics and chemistry, over the 20th century. With its relatively substantial historical focus on human intervention and process, however, we expect that geology’s openness to studies of a dynamic, interconnected ecosystem will have slowed its decline.

Biology, like botany and zoology, focuses on the study of living things. Whereas botany and zoology, however, are historically premised on the study and classification of whole organisms, the science of biology embraces all aspects of the workings of life—even extending to human beings. This catholic approach positioned biology to evolve over the course of the 20th century (continuing a process that had begun centuries earlier) from the study of discrete organisms to the study of webs of life, as well as cells and subcellular processes (Rosner 2002:95). The introductory biology course at Canada’s University of Victoria, for example, covers “biological chemistry, cellular diversity, membrane structure and function, energy transduction, DNA replication, mitosis and the cell cycle, meiosis and sexual life cycles, Mendelian genetics, gene expression, evolutionary theory, and diversity of prokaryotes, protists, plants, and fungi.” We expect that this emphasis on universal life processes will have bolstered biology’s position in the university relative to its category- and hierarchy-oriented siblings as structural blueprints of fixed hierarchies have given way to dynamic networks.

The fact that modern botanists and zoologists profess a deep interest in these dynamic processes and claim a sort of intellectual jurisdiction over them indeed strengthens our argument—these low-level processes could be and indeed are studied under the aegises of the historically hierarchy-oriented disciplines. The eclipse of those disciplines, we argue, will be observed not because they are shown to be scientifically “wrong,” but because the fixed, hier-
archival model of reality on which they were founded lost legitimacy. The process-oriented approach of biology, besides being consistent with a cosmological shift from hierarchy to process, is also consistent with a shift from divine to human actorhood; for example, the University of Victoria’s current course offerings in biology also include Economic Entomology (“the variety of measures available for pest control will be emphasized”12) and Plants and People (a look at “economically important plants and their products, sources of food, shelter, clothing, drugs, and industrial raw materials”13). Biologists care not only about what things are, independent of humanity, but about how things work, in relation to humanity.

Chemistry’s approach—and, increasingly, its subject matter—is fundamentally the same as biology’s, as manifested in the recent ascendance of biochemistry.14 We expect that the universalistic, process-oriented approach of chemistry—the science that is concerned with the workings of matter at the atomic level—will have been highly conducive to its persistence over the course of the 20th century. Compared to any of the sciences discussed earlier, chemistry seems to have grown over the course of the 20th century in scope and ambition, with dozens of subfields ranging from analytical chemistry to organic chemistry. With this range at its disposal, modern chemistry sees itself as perhaps the foundational science. Cambridge University’s chemistry department, for example, tells prospective students:

We like to think of chemistry as the “central science” as a knowledge of molecular structures and properties is crucial in our understanding a large part of science, from semiconductors to proteins and from the composition of interstellar clouds to the human genome. By studying chemistry you will acquire a range of skills and learn about ideas and concepts which address all the important questions in modern science.15

This all-embracing worldview is natural for a discipline that traces its historical roots to attempts to explain a wide range of natural phenomena by recourse to a few simple laws of behavior and makes the field a prime candidate for such industrial dabblings as a course taught at Cambridge University by a team of scientists from Amoco (“the chemical industry is one of the most successful parts of British industry and, unlike much of commerce, an understanding of fundamental scientific principles and the application of technology lies at the very heart of the business”).16 As the institutionalized power to know and do shifts from God to humans, chemistry should claim university resources that are unavailable to its disciplinary brethren, premised on the eclipsed model of actorhood.

Arguably, the processual science par excellence, however, is physics. Physics, the discipline that is concerned with the behavior of matter, hoists an even broader umbrella than does chemistry. Any aspect of the behavior of matter—from the coherence of subatomic particles to the paths of the planets—is in this discipline’s scope, flouting traditional categories and collapsing traditional hierarchies.17 The Department of Physics at Morocco’s Mansoura University, for example, includes research groups that are studying solar energy, electronics, glass, nuclear physics, optics, and physics theory.18 Among the natural sciences, physics perhaps has most frequently joined in interdisciplinary ventures (as in geophysics, biophysics, and astrophysics) as well as having been put to industrial application. Far from conceiving of the universe as a static hierarchy, physics seeks universal processes that apply to all matter (including human matter) and that are to be discerned by active human investigators.19 The only basic science that is more compatible with an integrated, dynamic view of the universe is mathematics, as discussed next. Thus, we expect that among the basic natural sciences, the relative decline of physics will be less significant than that observed for any other science save mathematics.

Mathematics is, among the natural sciences, perhaps uniquely well suited to revised templates of action and structure. In the newly institutionalized scheme, all phenomena are fundamentally interconnected and fundamentally similar, behaving in accord with the basic natural laws (Boyle and Meyer 1998). “Many modern physicists and philosophers (Albert Einstein being a notable example) maintain, with the early Pythagoreans, that nature is ‘essentially’ mathematical” (Cartwright, Psillos, and Chang 2003:23). While mathematics has long been a pillar of the university, understand-
The contemporary cosmology requires mathematics in a way that the outdated cosmology did not. Mathematics provides an abstract key to the universe, which humans can comprehend and therefore manipulate. In the past, understanding human behavior meant understanding the mind of God; today, understanding human behavior means building statistical models (Porter 2002)—for this reason, statistics has been called the most important development in 20th-century mathematics (Rosner 2002:200). In the past, understanding the natural world meant painstakingly observing and cataloging plants and animals; today, it means simulating the atmosphere with supercomputers. Modern universities understand this point well: The web site of the Department of Mathematics at the Universidad Nacional de Colombia speaks of the discipline’s power to illuminate “the most general structures of logical thought,” which can be applied to a “diversity of fields.” Although “pure” mathematics may bleed faculty to departments of applied mathematics and computer science, we expect that the foundational importance of mathematics to the currently institutionalized cosmology will have slowed or perhaps entirely prevented its decline over the course of the 20th century.

**Expected Overall Trend**

Although we have emphasized that certain fields are particularly well adapted to have evolved in a manner that is compatible with the global-institutional shifts we have described, it is worth restating that we expect to observe a decline across the basic natural sciences. Despite all the new interdisciplinarity and openness to “real-world” applications, the basic natural sciences (again, as opposed to the explicitly or implicitly “applied” natural sciences) remain one step removed from the remodeled reality—a dynamic assembly, motivated by human volition. To some extent, the basic sciences still observe the universe as it is presented to us by God. That universe may become less static and more dynamic, less hierarchical and more horizontal, and may be seen to be fundamentally ordered at ever-lower levels, but the basic natural sciences remain, at their heart, an ivory-tower enterprise—and pride themselves as such. Whereas disciplines like engineering and medicine aim to understand the natural world in the direct, mundane service of the human community, the basic natural sciences remain officially aloof from human application and intervention in the natural world. The basic natural sciences, even in their most progressive guise, retain the spark that has long animated scientific exploration—the empirical quest for the ultimate nature of reality. As Hawking (1988:193) noted in conclusion to his astrophysics blockbuster *A Brief History of Time*:

> If we discover a complete theory, it should in time be understandable by everyone, not just by a few scientists. Then we shall all, philosophers, scientists and just ordinary people, be able to take part in the discussion of the question of why it is that we and the universe exist. If we find the answer to that, it would be the ultimate triumph of human reason—for then we should know the mind of God.

It is in such sentiments—widely if implicitly shared among scientists in these disciplines—that one sees most clearly the philosophical link between the humanities and the basic natural sciences. The ultimate basis of this philosophy in the outmoded models of action and structure will, we hypothesize, be seen to have led to a slow but inexorable decline in the basic natural sciences’ position in the university.

**DATA AND METHODS**

We have laid out our orienting questions: How did university teaching and research emphases change over the 20th century, and why were the changes patterned as they were? And we have sketched the outlines of our argument: Changes in university priorities follow from changes in the framework of globally institutionalized reality. Now we turn to empirical matters. With what research design and what data can we document and begin to explain long-term, worldwide shifts in the overall teaching and research emphases of universities?

Given our objective to explore the notion that global-institutional frame shifts alter the university’s building blocks globally and across knowledge domains, we present data from a
worldwide sample of universities showing redistributions of emphases among disciplinary fields. This approach, like any, has drawbacks. For one, it trades off detail to underscore global-institutional effects across levels and domains of university knowledge. Given the richness of existing case studies, we believe that the sacrifice is warranted. For another, our research design foregoes tight quantitative analyses of independent-dependent variables because there are simply no acceptable ways of measuring independent variables as diffuse as changes in globally institutionalized reality.

The strengths of our approach, by contrast, lie in its potential to demonstrate the role of the overarching global-institutional frame in reconstituting the whole body of university knowledge on a worldwide basis. With reference to basic alterations in “action” and “structure,” we shed light on a great many changes in the university’s teaching and research priorities.

To document the relevant transformations empirically, we present longitudinal data that measure faculty composition worldwide over the course of the 20th century. Although the global-institutional shifts we describe were well under way by 1900, we focus on the 20th century because that century was pivotal for the university. The years covered by our data saw universities grow in number and size; international disciplinary organizations and funding bodies became widely influential in crystallizing the ascendant global-institutional paradigms of action and structure.

We use the faculty-level data to characterize changes in the university’s overall academic priorities. Of course, relative faculty size does not perfectly measure university activities in a given area: Not all faculty make equal contributions to or equal demands on the university as a whole. Nevertheless, relative faculty size has considerable strengths as an indicator, most notably because of its availability for a large number of country cases and its relative commensurability across different types of university organizations. Indeed, we know of no other indicator of teaching and research emphases (student enrollments, degrees granted, funding, and so forth) that has a comparable scope: Global-historical data sources are scarce.

The data on faculty came from three university directories: The Commonwealth Universities Yearbook (Association of Commonwealth Universities 1914–95), the Index Generalis (Montessus de Ballore 1919–55), and the World Guide to Universities (Zils 1971, 1976). The first two directories appeared originally around World War I, embodying the notion that knowledge that was shared across international boundaries might foment peace. All three directories included lists of faculty by disciplinary field (for example, physics: Binotti, King, Lo). The Index and World Guide included information on universities from around the world, while the Yearbook included only those universities that were located in British Commonwealth countries. Our data sources vary by period; here, we present the complete data from the Commonwealth Universities Yearbook, which accurately represent worldwide trends but avoid the artificial jags that would result from our changing case base were we to include all available data for each period.

From the available listings, we sampled one university per nation-state—preferring the most central, where centrality was assessed by official association with the state and/or prestige (in many cases, this meant choosing the national university). This sampling method—in effect, of the population of nation-states—follows from our argument: We sought a worldwide sample of universities on which to test our world-level ideas. The main alternative—taking a random sample from the population of universities directly—would result in a data set that was dominated by U.S. universities.

Although the comparison of national flagship universities to less-central universities is a question that merits further investigation, here, we restricted our inquiry to the central university in each nation. Besides the fact that data on noncentral universities appeared much less frequently (for some smaller nations, not at all) in our data sources, noncentral universities are much more likely than central universities to be specialized institutions. Including noncentral universities in our analysis, even if we were to average by nation so as not to give greater weight to larger nations, might have introduced a measure of bias that we preferred to avoid.

The lists of faculty by disciplinary field provided the raw data for our variables of interest. To construct these variables, we first created a
series of ratios for each university in our sample: for example, the number of basic natural scientists generally and by disciplinary field (astronomy, biology, botany, chemistry, geology, mathematics, physics, and zoology) over the total number of university faculty. We then averaged the ratios across university cases to come up with the average proportions presented here. We performed this operation at 10-year intervals from 1915 to 1995, later switching to 20-year intervals to increase our case base. This left us with four time intervals: 1915–35, 1936–55, 1956–75, and 1976–95.

In creating the faculty-composition variables, we relied on the disciplinary coding labels used by the editors of our data sources; for example, an astronomy professor to them was an astronomy professor to us. Fortunately, with three data sources, we were able to check for bias in these coding labels. We found none to affect our results substantially.

With respect to the question of disciplinary classification, it is worth emphasizing that we are not arguing that the official disciplinary classification of faculty members’ activities maps cleanly onto the faculty members’ actual research activities. As we noted earlier (and explore elsewhere in detail; see Frank and Gabler forthcoming), our argument accounts for intradisciplinary shifts as well as interdisciplinary shifts; thus, “zoology” in 1915 and “zoology” in 1995 were, in practice, somewhat different from one another. Official classifications, however, are precisely our object of interest in this article; thus, the indicator and the variable are one and the same. We argue that when it comes to academic disciplines, a name says less about the substantive nature of work in a given field than about the framing of that work: the story that the discipline’s practitioners tell about their history and their role. Kay (1993:16) referred to this storytelling as a discipline’s “representational practice”—with each discipline laboring “under the conviction that its own representational practice grasps the essence of life.” In this respect, the decline of zoology and the decline of “zoology” are one and the same.24

In short, the faculty-composition data allowed us to characterize shifts in the overall teaching and research emphases of universities for many countries worldwide over the 20th century. We used the data both to establish the empirical facts of change and to assess our argument’s capacities to explain them.

RESULTS

Our first observation is that our overall hypothesis is supported: Across the board, we observed declines in the faculty share of the basic natural sciences. There is a substantial amount of variance in the degree to which individual disciplines felt the loss—astronomy lost 89 percent of its share, while geology lost only 6 percent—but overall, the basic natural sciences lost a striking 38 percent of their share of the university faculty worldwide. Whereas early in the century, the investigation of the natural world under the auspices of the basic natural sciences was the task of nearly a third of the faculty members at the typical university, by the century’s end, it was the task of fewer than a fifth.25 We take this as strong support for our hypothesis that a shift in the globally institutionalized cosmology underpinning universities’ endeavors has diverted resources from the “pure” investigation of the natural world.

As we hypothesized, the sciences that faced the steepest declines were those that were oriented primarily toward the comparatively passive observation and classification of static entities. Botany and zoology, as Figure 1 shows, declined in near-lockstep—from 2.7 percent and 2.4 percent of university faculty, respectively, to 1.0 percent and 1.1 percent. Over the course of the 20th century, each of these disciplines lost over half its share of the universities’ faculty resources as their respective endeavors became more marginal to the modern university’s mission. To put it another way, early in the century, about 1 in 35 faculty members was a botanist; by the century’s end, only 1 in 100 was.

The decline of astronomy was even starker, particularly given that these data reveal its foothold in the university to have been surprisingly tenuous to begin with—considerably less than 1 percent of the total faculty. These figures may be somewhat shocking in light of the massively disproportionate amount of public attention that has been paid to astronomy. From the aforementioned Stephen
Hawking to Carl Sagan—long a veritable institution of public television—astronomy has enjoyed a romance with the public and has long boasted an unusually large number of amateur practitioners (Knight 2003:79). Our data suggest, however, that this public allure has not translated to faculty resources. As the ontological assumptions of the academy have shifted toward the processual and human-centric, we expect (although our data cannot definitively answer this question) that university astronomy has moved increasingly under the umbrella of physics. Although this joining with physics may mean that the incidence of astronomy teaching and research is underestimated in our data, the result is not a mere artifact; as we have emphasized, the label placed upon research in a given area is a telling indicator of the institutional underpinnings of that research. For example, if a professor who researched star clusters was called an astronomer in the 19th century and a physicist in the 20th, it suggests that we have reconceptualized her very enterprise in accordance with newly institutionalized models of action and structure. Furthermore, this result highlights the value of a wide-reaching sampling scheme. Surely, astronomy would seem to have enjoyed a greater share of faculty if we were to turn to U.S. universities (for example, our *World Guide* data revealed that as late as 1971, astronomers constituted 0.8 percent of the faculty at the University of Wisconsin–Madison and 1.2 percent of the faculty at Harvard University); our global data, however, revealed that astronomy was inessential (or, at best, highly marginal) for most universities.

Finally, Figure 1 demonstrates that geology demonstrated considerable staying power over the course of the 20th century. Its relative decline, in fact, was the least dramatic of any natural science’s: In the earliest period for which we have data, about 1.2 percent of the university faculty were geologists, and this proportion had barely declined by the final time point. What this finding means, as Figure 1 shows, is that a field with only half the faculty share of both zoology and botany early in the century had a greater faculty share than either of those fields later in the century. This result is something of a surprise, since geology (unlike, say, chemistry or physics) assumes, by definition, a categorical order, in which the physical matter of the Earth may be clearly designated.

**Figure 1. Changes in the Composition of University Faculty for British Commonwealth Countries: Natural Science Fields Employing Less than 4 Percent of University Faculty in Period 1**

![Figure 1. Changes in the Composition of University Faculty for British Commonwealth Countries: Natural Science Fields Employing Less than 4 Percent of University Faculty in Period 1](image-url)
Still the field accommodates human actorhood and assumes basic dynamism. As the dynamic, integrated model of the natural world gained currency over the 20th century, geology proved itself to be most readily adaptable to the “ecosystem” model and was buttressed accordingly. As Oreskes and Doel (2003:539) noted, though, this is a case in which the widely noted midcentury boost in national security funding interacted with shifting global-institutional currents to produce the robust field of geology we observed through the 1990s:

The ascendance of geophysics was not primarily the result of prior intellectual success. Rather, it was the result of an abstract epistemological belief in the primacy of physics and chemistry, coupled with strong institutional backing for geophysics premised on its concrete applicability to perceived national-security needs.

In Figure 2, we show further evidence of the broad decline in the basic natural sciences. The four disciplines included here—all disciplines that occupied a greater share of university faculty in the first period than any of the four discussed in this section thus far—without exception experienced a significant decline in their share of faculty over the course of the 20th century. Again, however, the differences in slope are telling.

Among these four, biology experienced the steepest decline, losing a full 44 percent of its share between the first and last periods. Biology—in contrast to chemistry, physics, and mathematics—assumes that a categorical boundary can and should be drawn around life (cf. Biglan 1973), a premise of declining legitimacy. Biology’s decline is thus consistent with our argument that fields that are most unequivocally premised on fixed hierarchies, rather than dynamic assemblies, and on divine, rather than human, actorhood should have been the worst off in the wake of the quickly shifting cosmology. Recall, however, that we observed even more dramatic losses for zoology (-54 percent) and botany (-64 percent)—sciences with the same fundamental subject matter as biology but with a much more explicit emphasis on classification, hierarchy, and passive observation, rather than dynamic processes and active experimentation.

Even more process oriented than biology are the disciplines of chemistry and physics, and we were not surprised to find their losses less significant than those experienced by biology, botany, or zoology. Both chemistry and physics lost approximately 35 percent of their faculty share—a full third, but proportionately less than the higher-level fields. Again, the relevant
axis of difference is adaptability to the new cosmology—chemistry and physics are both relatively compatible with a vision of a horizontal, dynamic universe, encompassing humanity and driven by universal processes (rather than its alternative, a static, rigidly hierarchical universe for humans to observe but not to affect).

Finally, among these four disciplines, the losses of mathematics were the least dramatic. Over the course of the 20th century, the share of university faculty studying mathematics went from about 4.7 percent to about 3.6 percent—a loss of about a quarter of the discipline’s original share. This relative persistence means that a discipline that was once eclipsed by chemistry, biology, and physics had a greater share of universities’ faculties in the final time interval than any basic natural science save chemistry (which it trailed, at the close of our observation period, by only a fifth of a percent and by now may be expected to have fully eclipsed). This discipline, with its emphasis on abstract principles and universal laws underlying all observable phenomena and its widespread application to all manner of human interventions in the natural world, has emerged as probably the dominant basic natural science in the university.29

Observers of the natural sciences (as opposed to the humanities) are much more reluctant to characterize shifts in teaching and research emphases as anything other than a teleological procession toward the known and actual “truth.” These data, however, strongly suggest that observed shifts among the natural science disciplines are best understood in the context of broad shifts in the globally institutionalized reality. As our fundamental models of structure and action shift, disciplines across the university rise and decline in accordance with their underlying assumptions about the universe. Natural science disciplines that emphasize a static hierarchy of being that is merely observed by humans see their faculty shares decline more rapidly, while those that emphasize a dynamic, integrated system of being that is actively manipulated by humans see their shares decline less rapidly.30

**CONCLUSION**

Harvard’s venerable Museum of Comparative Zoology is a museum not only of animal species, but of an entire eclipsed worldview—thousands of specimens of taxidermied birds, fish, and mammals are arranged by species behind glass cases, the natural world in perfect order for humans to observe and catalog but not to tamper with. Ageless, unchanging glass replicas of plant species are arrayed in careful botanical order; guidebooks tell of heroic Harvard professors who roamed Africa’s savage jungles in search of the perfect gorilla specimen to shoot, stuff, and triumphantly display among its fellow primates. The museum’s unifying cosmology is manifestly that of a past age—boundless diversity for humans to capture, classify, and gawk at. The net impression is one of an awesome natural world full of powerful, exotic, scary creatures and ordered by a divine logic. Furthermore, the clear presumption of the exhibit’s design is that the act of knowing involves merely observing, rather than experimenting. The visitor is there to be told what scientists have discovered about the order of the universe, not to discover anything himself or herself.31

The newly constructed Science Museum of Minnesota presents a powerful contrast, embodying the new cosmology of process and human empowerment (for good and for ill). Its raison d’etre is to involve and empower the individual in a dynamic universe. Interactivity is pervasive—even the dinosaur skeletons are outfitted with levers that allow visitors to move the beasts’ jaws. An exhibit on local waterways emphasizes rivers’ historical utility (children can play inside an actual tugboat and operate a toy lock and dam) and unified ecosystem (visitors can assemble a puzzle representing the web of life). An exhibit on physics emphasizes the discipline’s broad relevance to phenomena from the weather (make your own tornado) to music (play a violin and watch the harmonic waves the sound produces) to geometry (manipulate pendulums connected to a pen that is drawing figures for the visitor to bring home). The museum’s programs “strive to open minds, not just fill them.”32 This is our new vision of the natural world, and as it has risen to globally institutionalized dominance, academic disci-
plines that are incompatible with mind-opening empowerment in an interconnected ecosystem operating by universal laws have lost prominence in the university and elsewhere.

The manifestation of this shift in museums is evidence of the breadth of the global-institutional reordering that our data show among university disciplines. Again, although we emphasize adaptation by selection (with faculties of eclipsed disciplines being proportionately trimmed), we argue that intradisciplinary change has been occurring as well. The shifts we discuss have occurred in a fractal manner, manifest at both the macrolevel (the founding of institutes and universities) and the microlevel (shifts in syllabi and course offerings). Of course, these shifts have varied in pace across sites, but constant across sites has been the direction of change and—even more so—a pronounced trend toward global isomorphism. The varying case base that our sources made available for interrogation unfortunately does not permit detailed analyses of axes of international variation, but comparisons of our constant-case data set (which is, by definition, heavy on older universities) with our broader data set make clear that the discrepancy between core universities and newer universities decreased dramatically over the course of the 20th century—even as our case base grew, among the basic natural sciences the average absolute difference in faculty share between our constant-case sample and our total Commonwealth sample was nearly three times as high in our first period as it is in our last (Frank and Gabler forthcoming).

As our vision of the natural world has shifted toward the dynamic and interconnected, the very notion of discrete disciplines has begun to erode. Nonetheless, the vast majority of basic natural science research at universities continues to be done under one of the seven disciplinary headings discussed in this article. Disciplines that have been less amenable to the cosmology, as it is currently institutionalized, have declined particularly steeply, but each of these disciplines has suffered for its fundamental focus on the passively observing (even if through experimentation) human actor—as opposed to the actively manipulating human actor that is presumed by the "applied" natural sciences.

Throughout this discussion, we have made reference to the vast and informative literature on the history of science. Besides informing our historical discussion, prior work by sociologists and historians of science has firmly established the validity of our move to suggest that shifts among disciplines are due to something more than a march toward objective "truth." The natural sciences, thanks to this prior work, "are no longer seen as possessing a special epistemological warrant which makes their sociological analysis irrelevant" (Pinch 1990:87). We hope to contribute to these literatures both theoretically (by drawing attention to a global level of analysis and to the usefulness of the institutional literature in sociology) and empirically (by contributing much-needed data on a subject of wide interest). That is, we hope both to answer some longstanding questions in these literatures and to enable the asking of new questions.

Some have suggested that our approach overtheorizes a shift that may be more parsimoniously explained by reference to the historical coincidence of two world wars, each of which drove governments to fund and otherwise promote applied science at the expense of basic research. Certainly, we acknowledge that this mechanism played a role, as has been widely noted by historians of science (Rowe 2003:129; Smith 2003:166). We do not, however, believe that this fact challenges the validity or usefulness of our argument. For one thing, the applied/basic tension has always been present in scientific research—from the first astronomical observations for use in navigation to the founding of America’s land-grant universities (heavily focused on the study of resource extraction) with the Morrill Act of 1862, the promise of application to practical problems has always been an impetus for science. At the same time, whether their aim was to map divine creation or to uncover the unifying principle of physics, researchers in basic science have long felt threatened by the mundane projects of their peers in the technical sciences (Shinn 2003).33

The university occupies a privileged global-institutional position as the locus of knowledge that is officially recognized as legitimate and essential. While the impassioned language and positive reception of work decrying the com-
Commercialization of the university (Bok 2003; Slaughter and Leslie 1997) is testament to the symbolic walls surrounding the university as a site of basic research, we are not arguing that the university is or has ever been immune to practical exigencies. Because these exigencies are not new, if the applied sciences have gained prominence in the university over the past century—and they have—it signals a fundamental shift in the globally institutionalized model of what constitutes publicly legitimate knowledge.

The decline in many of the “basic” natural sciences and the rise in many of the “applied” sciences are best understood, we contend, not as a historical coincidence, but as one manifestation of profound shifts in the globally institutionalized cosmology. From this perspective, the “basic” natural sciences represent the corner of the university that is associated with the humanities—which have historically and symbolically been central as a project to find God’s fingerprints in the cosmos, but are out of place in a world that places actorhood on the shoulders of humans, rather than of their Creator. For fundamentally applied scientific research to become central to the project of the university, the university had to make ontological room for a field of human endeavor that was once regarded as deeply suspect. Exigencies of war are not sufficient to explain the shifts we observed—applied scientific research could have taken place in governmental laboratories or under the auspices of industry. Furthermore, our theory accounts for shifts across the university faculty—even among fields in the humanities, where the decline of classics and philosophy and the ascendance of hands-on arts training cannot be explained by global conflict.

The decline we have shown in the basic natural sciences, as noted, may seem wildly counterintuitive, yet this trend holds across our multiple data sources and is confirmed by UNESCO data on enrollment in courses that were analyzed by Drori and Moon (forthcoming). Although a complete discussion of shifts among the branches of learning is beyond the scope of this article, we show elsewhere (Frank and Gabler forthcoming) that massive growth in the social sciences (economics and sociology), as well as the aforementioned surge in the applied natural sciences (medicine and engineering), has taken up the slack for both the basic natural sciences and the humanities. The university is indeed “science-izing”—but for the reasons we discussed earlier, this change does not translate into proportional growth in the basic natural sciences.

Explorations such as these suggest the richness of a global-institutional perspective on change in the university. Revisions in the broad framework of “reality” seem to have reset, at least in part, the university’s teaching and research agenda worldwide. Of course, the work presented here is only a beginning. Shifts in the disciplinary composition of the natural sciences represent only one aspect of wider transformations that reconstitute the whole body of university knowledge. In future work, we hope to broaden, as well as deepen, our reach.
APPENDIX

Our data were drawn from the *Commonwealth Universities Yearbook* (Association of Commonwealth Universities 1914–95), the *Index Generalis* (Montessus de Ballore 1919–55), and the *World Guide to Universities* (Zils 1971, 1976). In the first two periods, we have data from the *Index* and the *Yearbook*; in the third period, we have data from the *World Guide* and the *Yearbook*; and in the fourth period, we have data from the *Yearbook*. Although we observed broad consistency across our sources, the figures presented here were drawn from the *Commonwealth* data. Appendix Table A lists all cases in our sample. Universities appearing in the *Commonwealth Yearbook* appear in bold. Constant cases appear in bold italics. In representing nations' names, we have observed conventions that were current in 1995.

### Appendix Table A. Sampled Nation-States, by Period

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### Natural Sciences in the University

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**NOTES**

1. We borrowed this parsing of reality—into action and structure dimensions—from Giddens (1979).

2. We have a book in press, cited here and elsewhere, that elaborates our argument using data from other branches of learning in addition to the natural sciences.

3. Earlier versions of this argument, applied to university history and primary-school curricular outlines, appear in Frank, Schofer, and Torres (1994); Frank et al. (2000); Kamens and Benavot (1991); and Meyer, Kamens, and Benavot (1992).

4. Neither do we mean to elide the fact that much “global” material originated in the United States and the West in general. We emphasize only that the conversion from Western to global institution requires fundamental change—a stripping of obvious particularisms and sectarianisms and the addition of universalisms and common goods.

5. Wong (1991) noted a similar transformation in primary school social studies curricula.

7. See http://www.botany.org/bsa/millen/mill1.html
8. Geology’s role in this respect has long placed it in a controversial position among creationists, who posit a relatively young and static Earth (Rosner 2002:96).
9. The first use of this term in the Oxford English Dictionary dates only to 1935.
10. Indeed, Schofer (2003) used geology as a case study of the very process of international institutionalization that our argument highlights.
14. In our data, biochemistry and biophysics are merged with biology, following from the fact that they represent biologists moving into border zones more often than the reverse. While biochemistry and biophysics together did grow significantly over the course of the 20th century, even together they remained only a fraction of the size of their “pure” parent disciplines. In the first period under consideration, for example, biochemistry and biophysics together were only a tenth the size of biology; by the final period, together they were a fifth the size of biology.
15. See http://www-teach.ch.cam.ac.uk/introcourses/faq.html. Claims such as this reflect the defensive stance that chemistry has long felt compelled to take toward lower-level (physics) and higher-level (biology) disciplines. Historically, disciplinary boundaries have been highly permeable. Each field has felt pressure to defend its sovereignty against neighboring disciplines that would usurp its substantive territory and thus its justification for independent existence. We argue that shifting definitions of actorhood and structure made this a losing game for certain disciplines over the 20th century.
17. The fact that both chemistry and physics can claim—with some legitimacy—to be the foundational science highlights the fundamental distinction between these disciplines and such disciplines as zoology and botany, each of which explicitly neglects an entire “kingdom” of being.
18. See http://www.mans.eun.eg/facscim/PhyDept/index.htm#Introduction
19. “It is often thought that if the theories of physics are true, they must fix the behavior of all other features of the material universe” (Cartwright et al. 2003:27).
20. Translated by the authors from http://www.matematicas.unal.edu.co/academia/programas/index.php
21. Of course, the reconstitution of academic emphases is not relegated to the university level. For instance, Goodson (1995:117–43) discussed the decline of rural studies and the rise of environmental studies in secondary schools in England and Wales—a shift that could easily be analyzed in our terms.
22. Further details regarding our case base and data sources appear in the appendix.
23. Even in 1995, the average number of universities per nation-state (excluding the outlier United States) was only 31 in the West and 11 in the rest of the world. In 1965, comparable numbers were 20 and 6 (Ramirez 2003).
24. Fisher (1990) noted the increasing philosophical distaste of late for disciplinary boundaries, which is consistent with the ascendant global-institutional order emphasizing systems and overarching principles. Even if “differentiation is more of interest to funding bodies than to philosophers” (p. 867), however, the disciplinary boundaries are so deeply institutionalized that they refuse to evaporate.
26. In fact, the motives behind the establishment of prominent official observatories have often had to do more with symbolism than with science (Bennett 1987:165; Smith 2003:159).
27. Although professors of “geology” have been combined with professors of “geophysics” for concision, we initially coded them separately, expecting to witness the ascendance of the latter discipline. We did indeed witness a rise—we observed no faculty members in geophysics in the 1916–35 period, but by the 1976–95 period, we observed twice as many geophysicists as astronomers.
28. Smocovitis (1996) and Mayr and Provine (1998) described biology’s tortuous path to acceptance as a unified science. Initially, the discipline of biology was regarded as an awkward marriage between zoology and botany (Simpson and Beck 1965:v). Even as biology gained traction on those outmoded disciplines, however, its practitioners felt threatened by chemistry and physics. Our data suggest that these latter concerns were well founded.

29. Philosophers have argued that their discipline is similarly universal in ambition and potential application. In the words of the American Philosophical Association, “the enhancement of our understanding of matters with which thinkers of great intelligence and sophistication have long been wrestling, which do not admit of definitive resolution and yet have far-reaching implications, is both challenging and central to the academic enterprise” (http://www.apa.udel.edu/apa/governance/statements/research.html, 2003). In actual substance, however, we argue that mathematics has found itself much freer to shed its emphasis on great thinkers of the past than has philosophy; accordingly, mathematics is seen as being more readily applicable to a broad variety of disciplines in the modern university.

30. As we have noted, we found broad consistency among our source bases with respect to overall patterns and trends. One discrepancy worth noting was that, through 1955–75, biology, chemistry, and physics performed even more strongly in the non-Commonwealth cases—marking upward progress where we observed a downward trend in the Commonwealth cases. Unfortunately, data on these non-Commonwealth cases are not available for 1975–95. Despite these different slopes, support for our theory is to be found in the fact that the two samples are converging on a common absolute distribution of disciplinary representation. Further research would shed helpful light on this question.

31. McEneaney (2000) noted that an intervening step between divine actorhood and human actorhood highlights the role of the scientific “expert”; note the parallel to the role of the “artistic genius” in the humanities.

32. See http://www.smm.org/get-involved/donorsandsupport

33. Arguments for the significance of the war years are challenged empirically by the fact that the natural sciences that seem most clearly to have grown during that period were botany and zoology, which went on to plummet precipitously (see Figure 1).

34. Another such exigency is cost; for example, if startup costs are disproportionately high for certain disciplines, the spread of those disciplines may be hindered. Even here, though, as we noted earlier, we see increasing isomorphism trumping cross-national discrepancies. Astronomy declined steeply, for example, even in our constant-case sample of relatively well-established universities.

35. “For years,” Kevles (1971, p. 9), noted, “technical students at Harvard and Yale lived in different buildings from the rest of the undergraduates, went to different lectures, sat apart in the college chapel, and earned degrees that Harvard and Yale proper held in suspicion if not disdain.”

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