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Displaying “The Natural World” for Public Curiosity:
U.S. Science Museum Transformations, from Lewis & Clark to the Exploratorium

By

Cheryl Ann Holzmeyer

A dissertation submitted in partial satisfaction of the

requirements for the degree of

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in

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of the

University of California, Berkeley

Committee in charge:

Professor Ann Swidler, Chair

Professor Neil Fligstein

Professor John Levi Martin

Professor Richard Candida Smith

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Abstract

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This dissertation analyzes the U.S. science museum field over time in order to examine institutional emergence, institutional transformation, and changing patterns of science boundary-work in displaying “the natural world” to publics. It investigates the constitution of the U.S. science museum field via 19th century natural history museums and world’s fairs, and the 20th century transformation of the field by industrial science museums and science center museums. Its theoretical contribution is to underscore the significance of material culture and its spatial dimensions to analyzing institutions, including patterns of boundary-work between publics and science. It argues that industrial science museums and their novel exhibitionary conventions arose as industrial material culture became framed as “applied science,” and as distinct from artifacts in the existing field of natural history museums. In addition, it argues that science center museums distinguished themselves from and proliferated more rapidly than industrial science museums due not only to new constituencies mobilized on their behalf, but also due to their de-emphasis on collections, particularly of rare and historical artifacts. These changes again facilitated new exhibitionary conventions. Thus the emergence, transformation and proliferation of institutions hinge on their material cultural dimensions, on multiple levels.

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Chapter 1: Displaying "The Natural World" for Public Curiosity – Museum Genealogies

In some sense, this dissertation started one day as I wandered through Seattle's new Science Fiction Museum, opened in 2004[1], the brainchild of Microsoft co-founder Paul Allen, also a major investor in the SETI (Search for Extra-Terrestrial Intelligence) Institute. The Science Fiction Museum was located at the Seattle Center, an area north of downtown developed for the 1962 Century 21 Exposition – the first world's fair in Seattle since the 1909 Alaska-Yukon-Pacific Exposition publicizing the development of the Northwest. While the 1909 fairgrounds became the campus of the University of Washington, the 1962 world's fair catalyzed the construction of Seattle's iconic Space Needle, the futuristic monorail that remains mostly a tourist stop, as well as the Pacific Science Center. The Pacific Science Center was the U.S.' first so-called "science center" museum – a place that I visited numerous times growing up, encouraged to become a "woman in science and engineering." Walking through the Science Fiction Museum, I was struck by the similarities between some of its exhibitionary themes and those at the nearby Pacific Science Center. Though at the Science Fiction Museum, the question featured repeatedly in exhibits was "What If?" – whereas at the Pacific Science Center, the pivotal question was "What Is?"

As I explored the Science Fiction Museum, I also looked for an exhibit devoted to Octavia Butler, the award-winning science fiction writer[2] whose voice stood out in that field not only for her writing, but also due to her race and gender, as an African American woman. Not knowing much about her, I had heard her read once at an event celebrating her book *Kindred* (1979) in Berkeley's Morrison Library – itself a kind of museum of old books. I came away inspired by her spirited wit and imaginative, critical, time-traveling "What Ifs" – bending genres I had never managed to be very interested in previously. Since she had also lived in the Seattle area during the last part of her life, I thought there might be a significant exhibit devoted to her work and legacy in the museum. I found no such exhibit – though she was mentioned in passing in one room. But I continued looking into Octavia Butler's narratives of science, technology and nature, while juxtaposing them with the high-tech "new economy" narratives of Paul Allen and Silicon Valley – which often seemed far removed from the material artifacts traditionally collected in museums, as well as from many everyday, analog landscapes – material culture writ large (Mukerji 2010). As I considered these narratives, certain tropes kept cropping up, especially: exploring a limitless frontier, remaking and redeeming "nature," and progress through technology. These themes were often in the background of the latest scientific breakthroughs and technological gadgets, however. This dissertation is partly an attempt to grapple with disparate narratives of "What If" and "What Is," and the different ways possibility and actuality may be articulated.

These interests led me to study collection and exhibitionary practices at U.S. science museums over time, including the spatial dimensions of these practices, in order to analyze changing patterns of science boundary-work and cultural cartographies of science[3] (Gieryn

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[1] The Science Fiction Museum has since folded into Allen's Experience Music Project, a museum at the same location. Though de-installed as a permanent collection in 2011, the Science Fiction Hall of Fame remains, and a new "Icons of Science Fiction" exhibit is scheduled to open in 2012.

[2] In addition to literary awards, Butler was the first science fiction writer to be awarded a MacArthur Foundation Genius Award, in 1995.

[3] Gieryn (1999) uses the term "cultural cartography of science" to refer to patterns of science boundary-work, or demarcations of *where*, *how*, *why, by whom* and *to whom* credible scientific claims are made – or not. I discuss

1999), in conjunction with changing historical geographies beyond museum walls. Since the 19th century, U.S. science museums have been pivotal sites for the collection and public display of science, technology and "the natural world." At the same time, science museums have been shaped by the upheavals of industrialization and de-industrialization that continue to transform the world, "natural" and otherwise. The rise of new media ecologies and infrastructures since the 19th century, including digital technologies, has dramatically altered the significance of museums as sites of knowledge, alongside shifting landscapes of local knowledge beyond museums. In this dissertation, I approach science museums as vehicles for analyzing histories of science popularization in the U.S., including the framing of "science" itself, especially vis-à-vis "the natural world." I analyze science museums and their exhibits as windows onto changing relations among scientific knowledge, society and culture over time, embodied in discursive and material practices – played out within and beyond museum walls, on science museums' "frontstages" and "backstages" (Goffman 1959).

What is a "Museum"?

A museum may be defined as a place oriented around a collection of "stuff," ostensibly set apart from the usual circuits of use and exchange – a collection of material culture, whether conch shells culled from the ocean or digital interactives featuring simulations of urban development. It is a built environment of a particular kind, intended not only to store, but to organize and display diverse things in ways meaningful to a particular group of people at a certain place and time. In so doing, it renders them "cultural objects," marking them off from the mundane, everyday world – whatever world tends to be taken for granted by visitors. As a built environment, a museum both contains cultural objects and embodies culturally infused spatial logics, institutionalizing various types of boundary-work in the process. It does so starting with its demarcation of "collections" from the world of stuff beyond, often accompanied by a partial or complete distancing from their provenance. Museums situate artifacts in new contexts of observation, manipulation and interpretation, including culturally particular taxonomies and narratives.

The term museum comes from the ancient Greek word *Mouseion* (*Μουσεῖον*), meaning "realm of the Muses," the goddesses of performed metrical speech,[4] the form of nearly all learning before books became widespread. In ancient Greece, *Mouseion* referred to a place set apart for study, in particular the "Musaeum" at Alexandria, which included the famed Alexandrian Library through which classical Greek texts were preserved for posterity. This early Musaeum, which stood from the third century BCE through the fourth century CE, established the museum as a place that assembled diverse sources and scholars for musing on all branches of knowledge. As Alma Wittlin puts it, "[It] seems to have depended on its general atmosphere rather than on its concrete features" (Wittlin 1949: 1). Wittlin notes that the Alexandrian Musaeum included statues of thinkers, astronomical devices, surgical instruments, elephant tusks, and rare animal hides. The eclectic character of the Musaeum remained a defining feature of museums through the Renaissance and modern eras, from *Wunderkammer* curiosity cabinets to the national collections of the Louvre and British Museum. Books published under the name

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these terms further in Chapter 2.

[4] These goddesses include Calliope (epic poetry), Clio (history), Erato (lyric poetry), Euterpe (music), Melpomene (tragedy), Polyhymnia (choral poetry), Terpsichore (dance), Thalia (comedy), and Urania (astronomy).

“Museum” also shared this synthetic profile. However museums have transformed over time, they were conceived as eclectic, generalist institutions.

Many museums’ implicit or explicit claims to “universalism” are problematic, however. In the past century, museums’ elite and Western cultural biases have been highlighted and critiqued by a wide range of people. These include anthropological scholars critical of museums’ representational claims; indigenous peoples and non-Western nation-states seeking repatriation of objects obtained in the context of colonialism; populist critics of museums’ role in promoting narrow conceptions of “art” and culture; and critics of museums’ elitist and culturally chauvinistic historical narratives – among others. So while museums may be eclectic in their range of subject matter and the materials they feature, there has been growing recognition that their collections are not “encyclopedic,” nor are they microcosms of the wider world, as many once claimed to be. Some scholars delving into the history of collecting to understand “proto-museums” have also emphasized that museum-like structures and collections have existed around the world since ancient times, not only in Greece (Kreps 2006: 457). This research indicates that myriad places that store and conserve valued objects, including Indonesian rice barns (*lumbung*) and Maori meeting houses, have museum-like aspects (Kreps 2006: 461-2). Thus museums are not defined by, nor do they convey, transhistorical, transcultural, or otherwise “universal” frames of reference. Rather, museums make contingent claims and counter-claims, through multifaceted objects – for which European and Anglo-American colonialism have often been significant historical contexts. At the same time, museums raise the general issue of the relation between “local knowledge” and practice, on the one hand, and non-local knowledge claims and institutions, on the other – whether structured by British or Chinese colonialism, capitalist or communist entities, states or corporations.

What is a “Science Museum”?

The term science itself comes from the Latin *scientia*, or “knowledge”; over time it has taken on the more specific meaning of knowledge based on systematic inquiry and observation. Meanwhile a science museum may contain a multitude of items and narratives, framing the stuff in its collections as “scientific” in a built environment that asserts physical and intellectual possession of “the natural world.” Science museums have done so since Renaissance times in a variety of ways, both through objects taken from nature (flora, fauna, rocks) and via human-made objects thought to represent knowledge of nature, or “applied science” (tools and technologies of many kinds). The line between “natural” versus “cultural” (or “artificial”) objects has often been unclear to collectors and museum curators, however. Making this determination was one of the most basic problems of classification and boundary-work to confront the nascent science museum field – alongside the issue of what was “valuable” to collect in the first place. These distinctions were, in turn, intertwined with other kinds of social and cultural boundary-work, including designations of the “primitive” and “civilized,” as well as the “anomalous” and “regular.” I discuss these issues further in subsequent chapters. Below I present an introductory genealogy of “science museums” in Europe, the U.S. and beyond. This summary of the development of European science museums over the course of the Renaissance and Enlightenment can only skim the surface of these histories. There has been no smooth, linear “development” of science museums over time. Yet certain patterns emerge that are important to understanding how U.S. science museums both drew on and departed from earlier, European frameworks of collection and display.

Collections & Curiosities: The European Renaissance and the "New World"

Natural history museums and cabinets of curiosity are arguably the earliest "science museums," first in Europe and later in the U.S. The European Renaissance, particularly in Italy, ushered in the rediscovery and development of both natural history inquiry and omnivorous collecting, leading to the emergence of early modern natural history museums. This was a period when, according to Paula Findlen, "all of Europe seemed to be collecting; museums, libraries, intricate gardens, grottos, and galleries of art filled the landscape of late Renaissance and Baroque Europe" (Findlen 1994: 2). According to Germaine Bazin (1967), these shifts came with the waning of the Middle Ages and growing orientation toward historical rather than Christian temporality. Classical art works, artifacts and learning – including Pliny's first century work *Naturalis Historia* – acquired renewed significance. As Findlen writes, "The collecting of antiquities and the passion for natural objects appeared in Italy before any other part of Western Europe; in both instances, a strong historicizing impulse on the part of Italian Renaissance humanists precipitated these activities" (Findlen 1994: 1). Findlen notes that the first professors of natural history were appointed in Pisa, Padua, and Bologna, and that natural history museums were established as a regular and esteemed part of the university curriculum by the 17th century. Natural history museums thereby became part of the educational and cultural infrastructure of the European Renaissance. The second half of the 17th century, particularly in Italy, was a period when many features of the modern natural history museum crystallized, and became entrenched in budding scientific societies.

Other types of "science museums" to appear in 16th and 17th century Europe included the technical and ethnographic collections of princes and aristocrats (Bedini 1965: 4),[5] who had sufficient wealth and leisure to devote themselves to acquiring goods as a cultural pursuit. Such connoisseurship and learning, or at least the display of collections, further enhanced their elite status. In Bourdieu's terms (1984), scientific and technical collections were "cultural capital" that augmented elites' economic capital, bolstering their privileged position in the social hierarchy. As Findlen puts it, "Through the possession of objects, one physically acquired knowledge, and through their display, one symbolically acquired the honor and reputation that all men of learning cultivated" (Findlen 1994: 3). The emergence of early modern science museums depended on elites with the capacity for the concerted collection and display of objects, despite Renaissance narratives emphasizing the rebirth of a universal humanism. Indeed, Findlen and other scholars (Mukerji 1983) have argued that elites' acquisitiveness was part of a more general shift toward greater materialism during the Renaissance.

Accelerated European collecting and the development of early modern science museums depended as well on the material and intellectual consequences of Europeans' global voyages of discovery and conquest, especially in the "New World." These unanticipated continents presented European explorers and naturalists with flora, fauna and indigenous inhabitants previously unknown to their societies, and found nowhere in the Bible or classical scholars.[6] The explorers spurred new European interest in collecting natural objects, both preserved and living, including collections to emulate indigenous displays. For example, as one historian writes, "[T]he spectacular gardens of Montezuma in Mexico provided a unique impetus

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[5] These collections were usually known not as museums per se but as "cabinets" in England and France or as "Wunderkammer" (wonder cabinets) in Germany.

[6] These sources included the Roman author Pliny, whose *Naturalis Historia*, based on fieldwork conducted during spare time from military duties, was the most influential natural history text in the Western world for centuries.

for the rapid development of living collections of species totally unknown to ancient Greek and Latin authors. These, of course, had no precedent in Pliny's work. Large-scale menageries and gardens of exotic species were soon the pride of princes and artists of southern Europe" (Porter 1991: 222). As preeminent empiricist Francis Bacon wrote, commenting on the relationship between new geographic and intellectual horizons:

> It is not to be esteemed a small matter that by the voyages & travels of these later times, so much more of nature has been discovered than was known at any former period…It would, indeed, be disgraceful to mankind, if, after such tracts of the material world have been laid open which were unknown in former times – so many seas traversed – so many countries explored – so many stars discovered – philosophy, or the intelligible world, should be circumscribed by the same boundaries as before. (Murray 1904, as cited in Findlen 1994: 3-4)

In sum, larger-scale historical processes of territorial exploration and acquisition catalyzed collecting and "possessing nature" in European museums.

This passion for collecting objects of the New World was accompanied by varied inquiries into their meanings, as part of the Renaissance's emphasis on empirical knowledge and scientific inquiry, including direct observation of nature rather than referencing classical texts. On the printed page, this shift was visible as "colorful bestiaries and herbals gave way to finely illustrated books of natural history" (Porter 1991: 222), indicating careful observation. Fantastic mythological creatures and monsters were gradually supplanted by detailed, realistic animal illustrations that would culminate in the 19th century with drawings by naturalists such as John James Audubon (later, such illustrations would in turn be outmoded by photography). Beyond the printed page, specimens were amassed and studied in natural history and ethnographic museums. Together, print media and museums formed staples of an early modern "media ecology," a concept discussed further in Chapter 2 – complicating the notion of "firsthand experience" on which museums' object lessons were supposedly based.

As it gradually became evident that the profusion of novel creatures in the Americas and beyond could not be contained within the cosmos of classical texts or the Bible, natural history museums were key sites where these empirical materials were collected and contradictions grappled with. Bacon advocated the creation of such museums as storehouses of "data." As Findlen writes, "In a sense, the creation of the museum [in the Renaissance] was an attempt to manage the empirical explosion of materials that wider dissemination of ancient texts, increased travel, voyages of discovery, and more systematic forms of communication and exchange had produced" (Findlen 1994: 3). In the early modern period, European discovery of New World flora and fauna led naturalists to relativize ideas of Aristotle and Pliny, more than overhaul classical natural history taxonomies. By the mid-17th century, as the Enlightenment gradually took hold, the natural history museum became "a symbol of the 'new' science, incorporated into scientific organizations such as the Royal Society in England, the Paris Academy of Sciences, and later the Institute for Science in Bologna" (Findlen 1994: 4). Natural history museums had become pivotal institutions in processes not only of collecting, but also taxonomizing, systematizing, and analyzing the natural world. They had become early scientific research institutions, in other words. In enabling empirical investigation and analysis of nature, natural history museums facilitated further interventions in it – including the development of new crops and agricultural techniques. These trends would deepen during the Enlightenment period of the 18th and 19th centuries, as knowledge of nature enabled its alteration, if not domination. Natural history collecting, in other words, set the stage for further manipulations of nature, from flora to broader landscapes.

The Enlightenment:
National Public Museums, Linnaean Taxonomy & the Cultivation of Public Reason

During the 18th and 19th centuries, several important shifts transformed European collections and museums, ultimately shaping U.S. science museums as well: 1) a shift toward more public museums, articulated with the growth of scientific inquiry and an increasingly democratic public sphere; and 2) a shift toward more systematic collection and display, particularly the use of Linnaean binomial nomenclature and taxonomies to organize natural history collections. Along the way, science museums became increasingly important as institutions for the public cultivation of reason.

As discussed above, during the Renaissance, European collecting accelerated and social elites amassed private collections for themselves and distinguished visitors. However, as these collections became more associated with scholarly inquiry, by proprietors and others, this association opened the way to greater public access to collections. By the late Renaissance of the 17th century, private collections had proliferated and were increasingly available to elite publics with the means and leisure to visit them. According to Bedini, "So numerous did the private collections available to the public become that…lists of them were being compiled and published as guides for travelers" (Bedini 1965: 8). Some of these private cabinets went on to become incorporated as public centers of inquiry, forming increasingly "modern" science museums, especially in England, Germany and Italy. Oxford's Ashmolean Museum (England), opened in 1683, was the first corporate body to receive a private collection and make it publicly accessible in a building constructed for that purpose. Other examples include Dresden's Kunst-und-Naturalienkammer (Germany), and the Museo Cospiano (Italy), which had subsumed the renowned Renaissance collections of the Aldrovandi museum.

This move toward more public incorporation of and access to collections continued through the Enlightenment in the 18th and 19th centuries, particularly with the founding of the British Museum in London in 1759, and the Louvre in Paris in 1793. The British Museum was formed from three private collections for which the British government agreed to take responsibility so that these objects could be available to the public, rather than only to elites. These collections included manuscripts and art, the Sir Hans Sloane collection of natural history specimens from Jamaica, as well as classical and ethnographic materials. Meanwhile the Louvre's opening followed the French Revolution, as an initiative to display royal collections to the French public. Hence in the later Enlightenment, shifts toward more public incorporation of collections were often articulated with democratic movements and nation-building projects, in which public spheres first emerged and cultural institutions placed new value on the public cultivation of reason. These aspirations set the stage for the first U.S. science museums, including Peale's Museum, discussed in Chapter 3.

There was also a trend over this period toward more systematic collection and display, in particular the use of Linnaean binomial nomenclature and taxonomies to organize natural history collections. During the Renaissance, collections included "natural and artificial curiosities," or both natural specimens as well as human inventions and mechanical devices. According to Bedini, "The earliest efforts at museum classification were attempted with natural curiosities, which were subdivided into the three categories of animal, vegetable, and mineral" (Bedini 1965: 25). Later, artificial curiosities were classified in terms of the materials from which they were made. In the 18th and 19th centuries, the loose “animal-vegetal-mineral” frameworks of Renaissance curiosity cabinets gave way to new categories and taxonomies, particularly with the publication of Linnaeus’ *Systema Naturae* in 1735 and the advent of Linnaean binomial nomenclature and species hierarchies. This system established a new basis for collecting, studying and displaying specimens in natural history museums.

The flipside of museums’ more systematic, “scientific” classifications and taxonomies were entities that did not fit these systems. In Dresden’s Kunst-und-Naturalienkammer, there was even a “cabinet d’ignorance,” displaying curiosities for which no names or categories had been determined, “and for which the visitors were invited to suggest identifications” (Bedini 1965: 11). At least initially, such unclassifiable anomalies were often deemed freaks and monsters, or *lusus naturae*, as discussed further in Chapter 3. As scientific knowledge of “the natural world” grew, such anomalies were often reassessed and “explained.” They were then deemed to either fit into existing classifications, into reconfigured taxonomies – or sometimes, the system in which anomalies were initially deemed problematic might itself be deemed invalid.

Civilizing the Machine in the Garden: National Landscaping & U.S. Science Museums

In the “New World,” such anomalies were especially prevalent since the lands that became the U.S. were still unfamiliar to the Europeans who established the first U.S. science museums. Processes of natural history discovery, collecting, territorial surveying, and nation-state building went together. Meanwhile, as artifacts and specimens were collected and placed in museums, in a variety of taxonomies and narratives, they were not only removed from their contexts of origin, but those contexts were often utterly transformed, if not destroyed, as Europeans domesticated “wilderness” landscapes. Territorial surveying not only facilitated natural history collecting, but also laid the basis for European settlement and colonization. “Salvage anthropology” was one response, with museums and other collectors scrambling after indigenous peoples’ material culture, with the expectation that these peoples and their cultures were becoming extinct (Cole 1985). Simultaneously, Native Americans were being forced off of ancestral lands to make way for these areas’ preservation as national parks, framed as “wilderness” (Solnit 1994; Spence 1999).

European-Americans’ ways of relating to the natural world of the nascent U.S. straddled the contradictions of both valuing “pristine” nature areas as sites of pastoral retreat, on the one hand, and aspiring to industrialize and transform nature into “natural resources,” on the other. Leo Marx has analyzed these contradictions and cultural dilemmas as the problem of “the machine in the garden” (Marx 1964; 2000), a metaphor that embodies Americans’ contradictory impulses toward nature, oriented toward both conservation and exploitation. The cultural problem of working through these contradictions – of “civilizing the machine in the garden” – is an on-going dilemma, with both narrative and material cultural dimensions. Ultimately, the cultivation of public reason at U.S. science museums takes place against this backdrop.

Chapter 2: Theoretical Overview & Methodological Discussion

Two Science Museum Portraits

By most accounts, the first U.S. science museum was Charles Wilson Peale's Philadelphia Museum, started in 1786 as a venture in cultural nationalism and source of supplementary income for Peale, an amateur naturalist and painter most famous for his portraits of American revolutionaries. Emphasizing the natural wonders of the new U.S. – especially the bones of a mammoth that were the foundation of Peale's collection – the museum attempted to demonstrate publicly Peale's contention that "Natural History is not only interesting to the individual, it ought to become a National Concern since it is a National Good" (Kohlstedt and Brinkman 2004: 10). Peale was not alone in this nationalist view of natural history, based on recognizing how territorial acquisition and investigation were intertwined. His project resonated with other elites and Peale rubbed shoulders with the leading politicians and thinkers of the day, in what was then the U.S. capital and most cosmopolitan U.S. city. In 1794 the museum moved from a building adjunct to Peale's home to a space in Philosophical Hall, home of Benjamin Franklin's American Philosophical Society. In 1811 it moved again to Philadelphia's Independence Hall, the site of the U.S. Congress before the government declared Washington D.C. to be the new capital city.

There, in the old State House, Peale's Museum took the form for which it is best known in his most famous self-portrait – in which Peale is shown standing before a raised curtain and ushering the viewer into his museum's Long Room, with its rows of cabinets and specimens. These collections were labeled and arranged according to Linnaean taxonomy, as well as cultural and social classifications, including distinct "races of mankind" (Sellers 1980: 92). Portraits of American revolutionaries and other contemporary elites hung near the ceiling, while stuffed birds and other creatures, as well as ethnographic artifacts, were arrayed below behind glass. Peale aspired for this arrangement "to shew a gradual link in the natural connecting chain" (Sellers 1980: 111), or Great Chain of Being, opening a Deist "Book of Nature" to visitors. Peale's Museum also included artifacts from the Lewis and Clark expedition into the Western "wilderness" – artifacts that fellow natural history enthusiast Thomas Jefferson arranged to have sent to the museum. The intended publics for these displays included farmers, merchants and mechanics, according to Peale (Conn 1998: 35), who argued that natural history collections were sources of both practical knowledge and moral uplift, especially in a nation where he, like Jefferson, deemed agriculture "the most important occupation" (Sellers 1980: 102). Conscious of its position at the edge of new political and scientific frontiers, Peale's Museum was a site for the physical and intellectual possession of nature in the early U.S., in classificatory frameworks that were not only or purely "scientific," but culturally infused and socially and geographically embedded. It was in many ways a metonymic space for "the natural world" in the new nation of the U.S. – a symbolic microcosm of nature and of knowledge about it, framed in national terms.

This description of Peale's Museum contrasts in multiple ways with science writer Natalie Angier's reflections on contemporary museums from the beginning of her book, *The Canon: A Whirligig Tour of the Beautiful Basics of Science*, which she begins by discussing her sister's decision to let family memberships at the zoo and science museum expire when her children turned thirteen:

> These were kiddie places, she told me. Her children now had more mature tastes. They liked refined forms of entertainment – art museums, the theater, ballet…No more of this mad pinball pinging from one hands-on science

> exhibit to the next, pounding on knobs to make artificial earthquakes, or cranking gears to see Newton's laws in motion…who bothers to read explanatory placards, anyway? (Angier 2007: 1)

While Angier is writing about the Oregon Museum of Science and Industry (OMSI), she could be describing any number of contemporary U.S. science museums, which now stretch from coast to coast, nestled into a substantially human-built national environment in which "wilderness" is institutionalized in national parks. These contemporary science museums often share exhibits, such as the popular Grossology exhibit Angier mentions, as well as IMAX theaters and large-scale blockbuster exhibits that vie for public attention with other forms of urban and suburban family entertainment.

The science museum Angier describes is the result of a complex set of historical transformations, both of science museums as institutions and of understandings both of science and the natural world. The Boston Museum of Science, for example, telescopes those complex developments in its own history. Founded by "gentlemen scientists" in the 19th century as the Boston Society of Natural History (BSNH), it was initially devoted to members' research more than public education. Yet today the Boston Museum of Science shares the madcap, hands-on ethos described by Angier, and caters to a younger, more diverse public. Its exhibits offer up a science smorgasbord rather than rigid classificatory frameworks for displaying the natural world and the Great Chain of Being. Industrial artifacts have found a significant place in the museum, as have the latest "new economy" breakthroughs in computing and biotechnology. Popular culture and a video game atmosphere infuse many displays, rather than the atmosphere of a temple aspiring to morally uplift visitors, who mostly appear to be children on elementary school field trips and middle-class families. For the most part, the displays they encounter are not behind glass, but invite people to touch and interact with them directly. At the same time, actual specimens and collections have mostly gone away – to other museums, storage rooms, or even disposal. In some ways more accessible to a greater diversity of people, with fewer boundaries to negotiate, the natural world and the scientific knowledge displayed in this new kind of science museum also appear relatively unmoored – detached from artifacts, taxonomies, and particular geographies. The museum does not have a sense of itself as a repository for explorations of the "wilderness," or as a place where the wilderness is ordered and transformed into knowledge of nature, except perhaps metaphorically. The binary of wilderness and civilization is no longer relevant in the same way.

Yet classifications and standards continue to shape science museums (and certainly science), though they may be embedded in built environments and visitors' experiences in different ways. Indeed, compared with Peale's idiosyncratic venture, contemporary science museums are in many respects more standardized places, characterized by greater institutional isomorphism (DiMaggio and Powell 1987). Many receive funding through the National Science Foundation's Informal Science Education program, which in turn articulates with national STEM (Science, Technology, Engineering, Mathematics) policies and initiatives. Meanwhile the Boston Museum of Science bears a very different relationship to scientific research than the early BSNH. The BSNH's natural history research has been displaced by more specialized laboratory science, whether at universities or corporate R&D departments, or more prestigious natural history museums at universities and in a handful of cities. These days, the research that more commonly takes place in science museums is "visitor studies" research, deploying surveys, participant-observation and other techniques of social science to analyze how people interact with and interpret museum exhibits. It is consumer-oriented market research for the science museum field, in other words. In its own way, this new science museum is also a symbolic space for "the natural world" in the contemporary U.S. However, it is a microcosm of natural knowledge framed less in national or preindustrial terms than in terms of regional habitat dioramas, placeless scientific principles and technology – industrial and "post-industrial." In addition, its displays are part of a complex field of urban cultural consumption and entertainment, including a media ecology increasingly shaped by digital cyberspaces alongside physical spaces.

These two portraits of U.S. science museums suggest several interrelated questions in the sociology of culture and of science, which guide this dissertation: 1) How and why do new institutions emerge, including new types of science museums, and influence broader fields, or not, over time?; 2) How and why do patterns of science boundary-work emerge and change?; 3) How do material culture and spatial orders contribute to the constitution of institutions?; and 4) How do material culture and spatial orders figure into science boundary-work and the constitution of credible knowledge claims? While this research began with the former two questions, the latter questions emerged as central to understanding historical transformations of science museums.

Ultimately, this dissertation's theoretical contribution is to underscore the significance of material culture and its spatial dimensions – at the level of both local places and broader landscapes – to theorizing about the emergence and transformation of institutions, including patterns of science boundary-work. More specifically, drawing on Goffman, this dissertation highlights the importance of "frontstages" and "backstages" to analyzing changing patterns of boundary-work at science museums. These changes include the emergence of new types of science museums with distinct framings of "science" and "nature," new relations between publics and science, and the changing significance of geography itself vis-à-vis "science" at science museums, particularly in the transition from an industrializing to a "post-industrial" nation-state. It argues that transformations of the science museum field, including institutional differentiation and changing exhibitionary conventions with distinct patterns of boundary-work, were intertwined not only with changing stakeholders, but also with changing national landscaping projects beyond museum walls – the ultimate backstages to science museums' exhibitions. To delve into these issues, below I first discuss theories of institutions and institutionalization, and then engage theories of boundary-work. Throughout, I delve into the importance of material culture and spatial orders to analyzing science museum transformations over time. In particular, I examine museum "front stages" and "back stages," and performative framings of "science" and "nature," in the context of broader historical geographies.

I) Institutions, Institutionalization & Naturalization:
Materiality and Standardized Forms of Displaying "The Natural World" to Publics

In theorizing about science museums as sites for producing and displaying "natural knowledge," it seems fitting to begin with discussion of institutionalization and its dovetailing with naturalization, or constituting the "taken-for-granted." Thus naturalization processes often go along with processes of standardization and institutionalization. Following Jepperson in *The New Institutionalism in Organizational Analysis*, I define an institution as "a social order or pattern" made up of "standardized interaction sequences" such that "routine reproductive procedures support and sustain the pattern…unless collective action blocks, or environmental shock disrupts, the reproductive process" (Jepperson 1991: 145). In other words, an institution is a social pattern sustained through conventions of interaction, including both cognitive schemas and practical actions. More ingrained, sustained and widely reproduced institutions are more institutionalized, as well as more naturalized, as "just the way things are." Organizations, including museums, may be analyzed sociologically as institutions, or "packaged social technolog[ies], with accompanying rules and instructions for [their] incorporation and deployment in a social setting" (Jepperson 1991: 147). The vast majority of sociological studies of museums center on art museums (Alexander 1996; Blau 1991; Bourdieu 1984; DiMaggio 1991 and 1982; Zolberg 1984 and 1981), though this may be changing (Jansen 2008). Science museums are institutions that, in their collection and display practices, frame "science" and "nature" in patterned, socially scripted ways. For example, they might demarcate industrial or "applied science" as distinct from natural history. In the process, they participate in various forms of boundary-work, as discussed further in the next section.

Museums' classificatory practices, in both collection and display, are a principal way in which they frame "science." Multiple levels of classification are core to science museums' displays and knowledge production, for publics and scientists – particularly given the affinity between systematic observation and acquiring natural knowledge. As Jordanova puts it, "All museums are exercises in classification…The ways in which the contents of museums are presented lead to, but do not fully determine, what visitors experience and learn. It is therefore important to understand the multiple taxonomies present in museums…." (Jordanova 1989: 23). She goes on to argue that there are three main types of classification at stake in museums: 1) the classification of the museum as a whole (e.g. as an art, history or science museum – or specific types of art, history and science museums); 2) classifications organizing collections and exhibits within the museum – i.e. shaping the museum's interior space; and 3) classifications of individual objects. Science museums' collection and display practices are shaped by all of these types of classification, which also institutionalize spatial orders, within the museum and vis-à-vis "the natural world" beyond museum walls. These spatial orders may be understood in terms of "frontstages" and "backstages," as discussed further below. Classifications do not float in abstract space but shape and define it, including in relational terms – marking off variously ordered, rationalized spaces in relation to non-ordered or dis-ordered spaces. Sometimes new classifications of "science museums" themselves emerge, such as industrial science museums, or science centers. Such institutional transformations are pivotal to this dissertation's analysis of changes in the U.S. science museum field over time.

Institutional theory's conception of an institution often tends to neglect the material dimensions of social patterns (DiMaggio 1982; Powell and DiMaggio 1991; Zucker 1988), including the classification practices and constitution of spatial orders that are so vital to understanding museums. For example, in analyzing cultural entrepreneurship in late 19th century Boston, Paul DiMaggio (1982) argues that the institutionalization of so-called "high culture" in the U.S. was not contingent on either material characteristics of cultural works or the class positions of audiences. Rather, the emergence of a new institution, "high culture," in a previously fluid urban cultural field depended on an entrepreneurial social group establishing the non-profit museum and the symphony as organizational bases for classifying "art." DiMaggio captures an important story of the transformation of the American art museum, including the importance of specialized spaces where practices such as "reverent" silence reinforce elite notions of decorum. Yet various artifacts he describes, like "Chinese curiosities" and "stuffed animals" (taxidermy), did not necessarily move to more popular sites after the establishment of "high-cultural," non-profit art museums. Rather, such objects often moved to other types of museums, including natural history and anthropology museums, reinforcing boundaries not between high- and low-brow culture, but rather "nature" and "culture." Attention to these issues requires taking seriously material culture and the enrollment of the natural world in museums and other institutions, beyond the frameworks emphasized by many institutional and organizational theorists.

Here scholarship that straddles sociology and science studies is helpful, especially work that examines the significance of material culture and practice (Pinch 2008; Carroll 2006; Latour 2005; Molotch 2003; Mukerji 1997; Kohler 1994; Star and Griesemer 1989; Callon 1986). As Trevor Pinch writes, "Institutions have an inescapable material dimension and part of the agency that actors bring to institutions is their work in producing and reproducing (and sometimes changing) the material dimensions of institutions. Likewise materiality itself exercises a form of agency… [W]e neglect the material aspect of institutions at our peril, especially if we want to understand institutional change. Institutional changes are often accompanied by rapid changes in technology—and technology is an important component of materiality" (Pinch 2008: 466). In other words, institutions are made up of both people and stuff, acting together in contingent ways. The actors relevant to the emergence of new institutions may include not only the most obvious entrepreneurial founders, but also changing technologies within and beyond museums, transforming landscapes of "the natural world," as well as the particularities of material culture. Especially significant may be things deemed "liminal" in particular museums because they "do not belong" in already institutionalized classifications and categories – such as industrial artifacts in a science museum field initially defined by natural history museums. Science museums' relations to material culture may also be pivotal to the question of how and why new institutions go on to influence broader fields, or not, over time – as in the case of science center museums compared with earlier industrial science museums.

To analyze such changes requires examining material culture and the spatial dimensions of its collection and display. Indeed Bowker and Star have referred to the power of classifications and boundaries as "the material force of categories" (Bowker and Star 1999: 3) – inseparable from the material world and its spatial dimensions, including material culture's ways of cohering with, resisting or otherwise subverting dominant classifications (Scott 1998). As Bowker and Star elaborate, "Whether or not a region is classified as ecologically important, whether another is zoned industrial or residential come to bear significantly on future economic decisions" (Bowker and Star 1999: 3). Such classifications find counterparts not only in state and corporate bureaucracies, but also in the cultural infrastructure of science museums. Ultimately, they contribute to institutionalizing particular social frames for science, nature, and acting on "the natural world." Bowker and Star refer to such institutionalization as a process of "naturalization," or, "stripping away the contingencies of an object's creation and its situated nature…. Objects become natural in a particular community of practice over a long period of time" (Bowker and Star 1999: 299). Put another way, objects become institutionalized in particular communities of practice over time – and there may be conflicts between the institutionalized frameworks of different professional communities, or between professionals and lay people with local knowledge.

Lastly, it is important to note that institutionalization at science museums takes place not only at the level of individual museums as institutions, but in the context of broader fields of cultural production (Bourdieu 1993). Science museums watch what other science museums are doing, and take their "moves" into account as they develop their own next exhibits, expeditions, or other programming. They particularly follow the activities of the largest, most prestigious museums – such as the American Museum of Natural History or the Chicago Museum of

Science and Industry – though these hierarchies change and differentiate over time. The two principal science museum movements in this dissertation – the industrial museum movement and the science center movement – were both attempts to reconfigure the science museum field in these ways, along with its exhibitionary conventions. These movements' trajectories and outcomes, particularly their significance for geographic dimensions of science boundary-work, cannot be understood apart from an examination of material culture and its spatial dimensions, however.

This dissertation also draws on the concept of media ecology, sometimes referred to in terms of media epistemology (Postman 1985), to better situate science museums in the institutional field of varied urban entertainment and media in which they operate and strategize. According to Postman, in a programmatic statement for the Media Ecology Association, "Media ecology looks into the matter of how media of communication affect human perception, understanding, feeling, and value, as well as how our interaction with media facilitates or impedes our chances of survival. The word ecology implies the study of environments: their structure, content, and impact on people." (http://www.media-ecology.org/media_ecology/index.html; accessed March 2012) Over the course of the 20th century, science museums grappled with a range of new media as potential competitors or sources of synergy. Museums grappled with amusement parks, film, TV, print media, and the Internet, among other media. Museums also operated in a world of wider-spread recreational travel, complicating the creation of novel displays for audiences. Science museums' institutional field of cultural production is shaped by this broader media ecology, along with the increasing heterogeneity of science museum types.

II) Science Museums as Institutions: Boundary-Work, Truth-Spots, Front-Stages & Back-Stages

As discussed above, science museums are institutions that, in their collection and display practices, frame "science" and "nature" in patterned, socially scripted ways. These framings of science and nature are themselves forms of boundary-work – demarcating what falls inside "science" and "nature," versus outside. They are also constitutive of other types of science boundary-work and broader cultural cartographies of science – for example, implicating particular forms of knowledge and particular professions as credible informants about "the natural world." Below I discuss sociological literatures on boundary-work and science, including the spatial dimensions of framing "science" and constituting credible knowledge claims.

This dissertation argues that one of the ways that science museums and their exhibitionary conventions have changed over time – transforming science museums as institutions – is in their patterns of science boundary-work. The literature on science boundary-work articulates with broader sociological theories about boundaries, as well as with more specific analyses of scientific practice and claimsmaking. Thus sociological scholarship on boundaries and classifications is both a burgeoning contemporary field of interest and a long-standing concern of the discipline (Lamont and Molnar 2002). Durkheim and Simmel, among others, investigated the causes and consequences of boundaries in social life, developing theories that analyzed these dynamics as part of the broad shifts thought to constitute modernity: the rise of capitalism, nation-states, and rationalization across social domains.

Durkheim, in particular, investigated relations between cognitive categories and social life, going so far as to argue that the basic categories of science – including space, time and causality – originate in the shared experience of social groups, and are then projected onto the natural world. The basic categories of the sacred and profane, he argued, are rooted not in any inherent properties of objects or nature, but in social life. "Impurities" result when the boundaries of these categories are transgressed, signaling a kind of danger to social life – a threat to the social and cognitive order. "Dirt" is not some essential substance from nature, but "matter out of place" (Douglas 1966; 2002: 44), according to Mary Douglas and other scholars who have built on Durkheim's work. Social solidarity is constituted or eroded as shared cognitive categories – common understandings of "dirt" or "nature" – are embedded in practice or transgressed. Shared cognitive categories and classifications perpetuate group patterns of perception and action, or actors' habitus. They contribute to reproducing social structures like families, professions and states. Far from being epiphenomenal to social life, such cognitive, cultural schemas are crucial dimensions of material practice, institutionalization and perpetuation of social inequalities, according to contemporary scholars such as Lareau (2003) and Bourdieu (1984).

The sociology of science – which itself has ambiguous boundaries, particularly vis-à-vis scholarship in the sociology of technology and environmental sociology – is especially rich in scholarship on classifications and boundary-work pertaining to natural and social orders. Thomas Gieryn (1999) first investigated boundary-work in the rhetorical constitution of credible knowledge claims and the demarcation of "science" from "non-science," arguing that these boundaries are ultimately *cultural* rather than arbitrated by any universal and socially transcendent "nature." Taking off from Thoreau's musing in Walden, "…as if Nature could support but one order of understandings," Gieryn argues that "Thoreau's legacy is a kind of 'cultural cartography' of science, a mapping out of epistemic authority, credible methods, reliable facts…" rather than a single "natural world" to which a monolithic science has privileged access (Gieryn 1999: 4). As he continues, "As individuals and organizations sift through a multiplicity of facts and theories using cultural maps drawn for them by proponents of a certain version of natural reality – choosing science while ignoring or discarding its impostors and rivals – they accomplish then and there the epistemic authority of science" (Gieryn 1999: 4). In other words, scientific claims are made and unmade in specific social contexts, not universally true as if emanating from or revealing the essence of "Nature" or "Science."

Gieryn goes on to specify three particular types of science boundary-work, taking place in distinct social contexts: 1) boundary-work aimed at expulsion of rival epistemic authorities; 2) boundary-work to expand scientists' jurisdictional control over a given ontological domain; and 3) boundary-work to bolster or maintain scientists' autonomy. Together, these patterns of boundary-work constitute cultural cartographies of science, as theorized by Gieryn – cultural spaces for constituting or discrediting knowledge claims. Put another way, science boundary-work takes place through discursive and material practices that establish certain knowledge as "scientific" and more credible than other knowledge. As Gieryn comments on the simultaneous mutability of these cartographies in contrast to the persisting authority of science, "[L]ooked at sociologically, these maplike representations become the linchpin of interpretive explanations of the quite stable and large epistemic authority of science" (Gieryn 1999: 4). Though social groups, objects and claims may change in mapping "science," drawing up the map continues to be important to partitioning credibility in the contemporary world. Sometimes these maps are negotiated more loosely via "boundary objects," including museum specimens that are naturalized in distinct ways by different actors, such as among professional scientists and amateur naturalists (Star and Griesemer 1989). Bowker and Star (1999) emphasize boundary objects as agents of coordination among disparate communities of practice.

The social boundary of central importance to analyzing U.S. science museums over time – particularly transformations from 19th century natural history museums to 20th century science centers – is the boundary between scientists and publics, or experts and lay people. Here the most relevant boundary-work does not involve expulsion of rival epistemic authorities or expansion of scientists' jurisdictional control over a given ontological domain – the first two types of boundary-work discussed by Gieryn. Rather, boundary-work between scientists and lay publics is a form of protecting autonomy, while at the same time negotiating relations with the diverse groups that make up these "publics." These groups include young people who may train to be future scientists, taxpayers who fund scientific research and sometimes vote on legislation pertaining to scientific research, and consumers of scientific research in the form of medical and other technologies. There is a more complicated dance in this kind of boundary-work than in either expulsion or expansion oriented boundary-work. It is boundary-work to engage the public and invite its understanding and participation, its "interactivity" and even critiques – but only up to an unspecified point. Science museum exhibits that have gone "too far" for some in critiquing science and technology, including by incorporating critiques from activist publics, cross the mercurial line from "engaging" to "polemical."

Some scholars argue that boundary-work between scientists and publics should not be framed as between science and "outsiders," but rather as integral to the system of constituting credible knowledge claims. As Latour writes of this more dialectical dance, drawing on his five-loop model (Latour 1999: 100) of the "circulatory system of scientific facts," including the loops of instruments, colleagues, allies, public representations, and linkages among them:

> Contrary to what is often suggested by science warriors, this new outside world [of public representation] is no more outside than the three previous ones [of instruments, colleagues and allies]…[I]nformation does not simply flow *from* the three other loops *to* the fourth [of public representation], it also makes up a lot of the presuppositions of scientists themselves about their objects of study. Thus, far from being a marginal appendage of science, this loop too is part and parcel of the fabric of facts and cannot be left to educational theorists and students of the media. (Latour 1999: 105-6)

This perspective informs this dissertation, situating science and technology firmly *within* rather than outside of society and culture in general, including relations with publics. This perspective calls for analyzing practices of publicly displaying "science" as integral aspects of scientific culture in a given time and place, embedded in and shaping perceptions of credibility, constituted by both diverse publics and scientists (Gregory and Miller 1998; Hilgartner 1990; Mellor 2003; Shinn and Whitley 1985). Scientific culture includes both high-brow and low-brow culture, as well as overarching Western cultural narratives and images (such as the "primitive" and "civilized") – though these often appear in more sanitized forms in professional scientific practices, or at high-brow natural history museums compared with world's fairs. Likewise, science museums have been and are crossroads for a wide spectrum of knowledge-holders, including those officially sanctioned as scientists as well as amateur naturalists and lay epidemiologists.

Such a perspective implicitly critiques a diffusionist model of science popularization, in which scientific knowledge is assumed to originate only in sanctioned research sites and then percolate elsewhere. This point speaks to Gieryn's other work in the sociology of science, on "truth-spots," arguments that this dissertation seeks to go beyond. Studies of material culture and of diverse sites of scientific practice inform growing recognition of the heterogeneity of scientific practice and the constitution of credible knowledge, whether for scientists or broader publics. Just as "dirt" may be "matter out of place," scientific "rubbish" or "bunk" is often defined partly by *where* it appears, and with whom. Gieryn proposes a sociological conception of "truth-spots" that captures both the site-based *and* material cultural aspects of places: "Truth-spots are 'places' in that they are not just a point in the universe, but also and irreducibly: (1) the material stuff agglomerated there, both natural and human-built; and (2) cultural interpretations and narrations (more or less explicit) that give meaning to the spot" (Gieryn 2006: 29 n. 3). For example, Gieryn analyzes how Walden Pond constitutes a truth-spot for Thoreau, as a "register of authenticity" for his claims "about life, the universe, and everything else" (Gieryn 2002: 114), as well as how the city of Chicago constitutes a truth-spot for early 20th century "Chicago School" social scientists, who variously emphasize its laboratory and field-site characteristics (Gieryn 2006). This scholarship questions the transcendent and universal status of many scientific claims, underscoring that they are very much historically and socially situated, including in the particularities of material culture and place that contribute to assembling them, such as science museums. In other words, science is not a "view from nowhere," but from particular places, things, and embodied observations. Feminist scholars have contributed to this discussion by emphasizing standpoint epistemologies and all knowledge as "situated knowledge" (Haraway 1990). Geographer David Livingstone, in *Putting Science in Its Place*, writes, "While monumental efforts have gone into constructing 'placeless places' for the pursuit of science…there are questions of fundamental importance to be asked about *all* the spaces of scientific inquiry" (Livingstone 2003: 3). He demonstrates this claim by delving into places ranging from museums and botanical gardens to zoos and hospitals, broader national and regional geographies, as well as the circulation of scientific representations among places.

How do science museums relate to other key sites of science? While Gieryn argues that field-sites and laboratories have "emerged over historical time as privileged truth-spots," often counter-posed in their "distinctive epistemic virtues" (Gieryn 2006: 5), natural history museums and other collections-based institutions that predated the laboratory revolution were characterized by aspects of *both* field-sites and labs. In ideal-typical terms, laboratories are places where discrete elements of the natural world are collected for systematic investigation, reinserting objects from locations and temporalities beyond the lab into their own artificial settings in order to conduct experiments that produce knowledge. They are places designed to "control for" the variability of the world beyond, except for the variables under investigation – sites of reconfiguration of surrounding natural and social orders (Knorr Cetina 1999). Field-sites, meanwhile, are in many ways "non-labs": places that are themselves under scrutiny and where their unique features and "uncontrolled" aspects are central to the type and credibility of knowledge at issue[7]. Science museums share aspects of both laboratories and field-sites by being places more "in the world" than labs, yet less than field-sites. Science museums and the things they contain are set apart from the world and its various "field-sites," yet they are usually not places for systematic experimentation. As Livingstone describes museums as scientific sites, "In these chambers the aim…was less to manipulate the natural world by experiment than to arrange it through classification" (Livingstone 2003: 29). Things tend to remain more intact in museums,

[7] As Gieryn puts it, "The field carries with it an idea of unadulterated reality, just now come upon. Certain field-sites become unique windows on the universe, revealing only at this place something that cannot be moved or replicated in the laboratory." (Gieryn 2006: 6)

which often strive to preserve them for posterity, though removed from their original contexts and placed in alternative classificatory contexts.

Science museums recontextualize things in ways that may foreground place or placelessness. For example, science museums sometimes try to contextualize specimens by placing them in habitat dioramas that resemble field-sites, or they create immersive environments as elements of exhibits on applied science, industry and/or technology. At other times, science museums present scientific principles, such as principles of thermodynamics or electromagnetism, outside of any social or cultural contexts, as if they existed in a vacuum. Thus both lab and field spatial logics may be constructed in museums as sites of material cultural collection, accumulation and classification. These logics are an implicit means of classifying scientific knowledge itself, as place-based or placeless. Analyzing these spatial patterns at different types of science museums, from natural history museums to science centers, reveals key historical shifts in the roles of material culture and place in constituting credible public knowledge claims, as well as in constituting articulated boundary-work. Science museums may also contain research labs and sponsor field expeditions; the largest natural history museums tend to support both types of research.

An overarching point is that science museums, like laboratories and field-sites, are fruitful to analyze as relational spaces. Here I take a cue from Knorr Cetina's approach to laboratories (1999), and conceive of science museums as "*relational* units that gain power by instituting *differences* with their environment" (Knorr Cetina 1999: 44). As she continues, "[O]ne can link laboratories as *relational* units to at least three realities: to the environment they reconfigure, to the experimental work that goes on within them and is fashioned in terms of these reconfigurations, and to the 'field' of other units in which laboratories and their features are situated" (Knorr Cetina 1999: 44). I argue that science museums are most fruitfully conceived as relational units along these same dimensions, though their scientific work is oriented toward classification and exhibition rather than experimentation per se. Science museums are places set apart – places defined by their assertion of physical and intellectual possession of the natural world, through their collections and exhibitionary practices. Rocks, flora, fauna and human-made artifacts take on new, "scientific" meanings because of their placement in science museums and the spatial orders that set museums apart from landscapes beyond, including sites of artifact provenance.

In order to analyze the social dimensions of spatial logics in the constitution of public knowledge claims at science museums, it is useful to draw on Erving Goffman's concepts of "backstage" and "frontstage," as well as a broader geographic perspective than Gieryn's notion of "truth-spots" suggests. First, regarding Goffman's dramaturgical perspectives on social life, core to his theoretical presentation in *The Presentation of Self in Everyday Life* (Goffman 1959) are the notions of a frontstage and backstage in social interactions. The frontstage is akin to where actors are "in character," performing their expected roles upon the stage. In Goffman's view, such behavior extends to everyday life, where people present themselves publicly in their "frontstage" versions of themselves – performing whatever roles are expected in order to get by, whether that means keeping their job or not alienating their in-laws. However, "backstage," they may share all sorts of gossip, expressions of disgust, or other discredited emotions with their co-workers, spouse, or friends. They may dress in jeans in and a T-shirt rather than a suit or uniform. They may sing off-key.

This dramaturgical paradigm is especially useful for thinking about boundary-work at science museums, due to its combination of spatial concepts and "impression management," including the constitution of credible knowledge claims. It is also useful given the complexities of boundary-work between scientists and publics, where publics are not assumed to be *a priori* "outside" of claims-making and scientific culture, as discussed above. While Gieryn does not engage Goffman's work, Stephen Hilgartner draws on Goffman's dramaturgical framework in his book *Science on Stage: Expert Advice as Public Drama* (Hilgartner 2000). In this and other work (Hilgartner 1990), Hilgartner demonstrates the complexity of boundary-work between scientists and publics, and the shortcomings of a diffusionist model of scientific communication. This dissertation takes a cue from Hilgartner's approach to boundary-work between scientists and publics, while examining science museums as spatial media in which the notions of "frontstages" and "backstages" correspond to spatial orders within museums and beyond. For example, museums' exhibitions, including their spatial layout, constitute a frontstage in their presentations of "science" and "nature." Meanwhile museums' backstages may include not only the non-public areas where museum staff study specimens and conduct research, but also landscapes and geographies of collecting and applied science beyond the museum.

A broader geographic perspective than Gieryn's notion of "truth-spots" is needed in order to adequately analyze the role of place and spatial logics in constituting public knowledge claims at science museums. Natural history and other types of science museums are not discrete sites of science or "truth-spots" akin to the oracle at Delphi, as in Gieryn's theoretical framework for analyzing the role of place in constituting credible knowledge claims. Rather, science museums are variously embedded in geographies and networks of material culture contoured by nation-state and colonial territorial incorporation, as well as trade and commercial relations – particularly through their collections, if they have them. These geographies are crucial to understanding the material culture at science museums, and the role of science museums in mediating relations among disparate places and peoples, including through their production of scientific knowledge that purports to transcend worldly interests and powers. As these broader geographies and networks of places have shifted over time, so have science museums' collection and/or display practices (including representations of place within museums), intended publics, and overarching missions.

One notable study of a kindred institution, the botanical garden, analyzes these broader geographies vis-à-vis science museums. Lucile Brockway's *Science and Colonial Expansion: The Role of the British Royal Botanic Gardens* (1979) draws on world-systems theory to gain analytic leverage on relations between the Kew Gardens and the broader geographies and networks of places in which they are embedded. As Brockway's book demonstrates in the case of the Kew Gardens:

> Just as private and governmental enterprise cannot be rigidly separated in colonial expansion, neither can pure and applied science be separated on the voyages of exploration and in Kew's later activities (188-189)…Knowledge flowed from center to periphery along this [botanical] network, from periphery back to center where it could be redistributed…At very little cost to Britain, Kew had searched for economically useful plants, most often in South America, had improved them, and transferred them to Asia, thus participating in extending the plantation system to Asia (190)…Through its scientific development of the plants transferred, Kew converted knowledge to profit and power, for the Empire and for the industrial world system of which Britain was then the leader. (Brockway 1979: 192)

Likewise, 19th century U.S. natural history museums were also intertwined with processes of national territorial surveying and incorporation. Collection-building and nation-state building went together, as discussed further in Chapter 3. These relations were an extension of the broader phenomenon, introduced in Chapter 1, of European exploration and colonialism leading to collection-building, first at private "cabinets of curiosity" and later at public museums. Collections displayed at 19th century world's fairs, which catalyzed the collections of many early industrial science museums, were enmeshed in similar geographies. Meanwhile, industrial development fundamentally transformed "the natural world" of natural history. Habitat dioramas encapsulating "wilderness" became elements of conservation education and salvage anthropology. This dissertation approaches these broader geographies and landscapes as the ultimate "backstages" to the "frontstage" exhibitions at science museums.

While Brockway draws on world-systems theory to make sense of these broader geographies, I find it useful to go beyond a merely political-economic approach to geography, to include cultural narratives and, indeed, to approach landscapes themselves as forms of material culture (Mukerji 2010). As Mukerji writes, "Landscapes or built environments contain distinct lessons about material culture and human life. Land that shows the effects of human activity is material culture, but is often less clearly bounded than other cultural objects and more vividly intertwined with nature" (Mukerji 2010: 543). While a political-economic approach to geography leads to important insights, as demonstrated by Brockway, it neglects such cultural dimensions of relating to nature. These include the diverse representations – including narratives – of the natural world constituted by scientists, publics, and others, as well as the complex cultural dimensions of consumption and production (Biernacki 1995).

Such an approach dovetails with Goffman's dramaturgical analysis of social life, by opening up analysis of how spaces are intertwined with narratives (Nye 1997), including the spaces of broad urban and national landscapes. As some geographers have argued, "Theater is a valuable metaphor and analytic tool by which to understand the creation, display, utilization, and consumption of landscapes" (Walker 1997: 163). This approach allows for analysis of landscapes and geographies in both political-economic and cultural terms. As Richard Walker elaborates, "We are both humanists and scientists in the bud, and the divisions between the cultural and materialist turns of mind among intellectuals have more to do with divisions of labor in academia than with absolute and indelible schisms within human life. I therefore end with a plea for overcoming false dualisms in geography and neighboring disciplines, and for the promiscuous mingling and mutual education of cultural geographers and political economists." (Walker 1997: 173) Ultimately, in discussing long-term, large-scale shifts in the backstages of U.S. science museums, I propose the concept of "national landscaping projects" to capture political-economic and cultural patterns characterizing the transformation of "the natural world" into human geographies of "second nature" (Cronon 1991). This concept facilitates reflection on science museums, per above, as "*relational* units that gain power by instituting *differences* with their environment" (Knorr Cetina 1999: 44). The concept of "national landscaping projects" also enables reflection on the material cultural and narrative dimensions of "civilizing the machine in the garden," as introduced in Chapter 1. I argue that "civilizing the machine in the garden" is the central cultural and political-economic problem at stake in displaying "the natural world" to publics, including framing STEM education for the future, based on both frontstage and backstage views, as discussed in my concluding reflections in Chapter 6.

Methodological Discussion:

My dissertation examines the emergence of the U.S. science museum field via 19th century natural history museums, and the 20th century transformation of the field by industrial museums and science centers. Integral to this analysis, I examine three "museum movements" that transformed the U.S. science museum field in the 19th and 20th centuries: the 19th century movement to establish natural history museums apart from dime museums; the industrial science museum movement of the 1920s and 1930s; and the science center movement of the 1970s and 1980s (and arguably beyond). To analyze exhibitionary, institutional and field-level transformations of U.S. science museums over time, my research draws on varied archival and secondary sources, as well as participant-observation at contemporary science museums. It also draws on interviews with science museum professionals and/or those working in the field of informal science education (ISE), as a guide to navigating archival records and contemporary trends.

For the 19th century, I draw more heavily on secondary sources, in order to survey the range of natural history institutions that emerged during that period, including the most significant natural history museums that continue to be leading institutions today (The American Museum of Natural History, The Field Museum, and the Smithsonian's National Museum of Natural History). Focusing on secondary sources also enables me to survey the broader contexts of natural history collection-building and museum development during the 19th century, including territorial exploration and incorporation, geographic surveying, world's fairs, and the development of an urban-industrial infrastructure and consumer culture. These contexts provide insight into how material culture and its spatial dimensions have mattered to establishing the institutional baselines for the U.S. science museum field, particularly in the formation of natural history collections, as well as distinct types of exhibitions, such as habitat dioramas.

For the 20th century, I draw not only on varied secondary sources, but also on primary archival research into the industrial museum movement and science center movement. This research includes several science museum case studies and archival research at the Association of Science Technology Centers (ASTC), an organization established by the science center movement to institutionalize science centers as "science museums" and expand the field overall. My science museum case studies, articulated with the industrial museum and science center movements, include: 1) the Chicago Museum of Science & Industry (MSI), opened in 1933 as the U.S.'s first industrial science museum – part of a broader contemporary movement to establish such museums in the U.S. to "catch up" with Europe – and later active in the so-called "science center movement"; 2) the Boston Museum of Science, founded in 1830 as the Boston Society of Natural History, and reinvented (and renamed) in 1943 as a hybrid industrial science and natural history museum; like the MSI, also later active in the "science center movement"; and 3) the Exploratorium, founded in San Francisco in 1969 as a science center, and perhaps the most influential player in the science center movement worldwide. These case studies represent a spectrum of historical founding dates and geographic locations (indeed, a spectrum of historical-geographic contexts of institutional emergence), coupled with a varied sample of science museum "types." For each science museum case study, I draw on founding and/or reinvention documents, annual reports, exhibition files, internal planning documents, audience data, and oral history interviews, among other documents, in order to analyze institutional and exhibitionary patterns over time (i.e. what is displayed, how, and to what ends). I focus particularly on junctures of institutional founding and re-invention, and their material cultural dimensions.

I again draw on secondary sources to analyze these 20th century institutional shifts in their broader social and historical contexts, including changing environmental and geographic contexts (e.g. Conn 1998; Opie 1998; Leach 1993; Cronon 1991; Kohlstedt 1979; Kasson 1976; Marx 1964). In this regard, my case studies not only exemplify distinct types of science museums and museum movements, but also a range of geographies implicated in distinct periods and patterns of U.S. territorial incorporation and construction of the national urban-industrial built environment. For example, the Boston Society of Natural History was founded at a time when the "U.S." did not extend West of the Mississippi, while the Exploratorium was founded in 1969 at the edge of the Pacific, when the U.S. had not only long since consolidated its continental territory, but established an extensive network of overseas territorial footholds. Examining U.S. national spatial orders at different historical junctures, particularly in conjunction with the spread of new types of science museums and exhibitions, enables analysis of their relations to spatial orders and exhibits inside museums. These exhibits may feature geographic representations ranging from landscape displays[8] and attempts to recreate entire outside environments inside the museum, to the presentation of "placeless" scientific principles, where science seems to "speak from nowhere." These relationships between museums' internal and external spatial orders indicate how relatively "exotic" versus mundane the worlds of science museums are in various times and places, including how relatively nostalgic, contemporary or futuristic the worlds of science museums may be – if they have any historical-geographic orientation at all. These relationships also indicate how relatively "human-made" (industrialized, "developed," technological, engineered) versus "nature-made" the worlds inside science museums are in different times and places, and at different types of science museums. William Cronon (1991) has referred to this distinction as "first nature" versus "second nature," in his work analyzing the relations between social and environmental histories.

[8] Other scholars, particularly Karen Wonders in her fascinating book *Habitat Dioramas: Illusions of Wilderness in Museums of Natural History* (1993), have also analyzed these relations in their studies of science museums – but this relational approach remains the exception; most analysis ignores the ways in which museums are relational spaces.

Chapter 3: The 19th Century Emergence of the U.S. Science Museum Field: Nautral History, *Lusus Naturae* and "Science" Boundary-Work

The U.S. science museum field emerged gradually over the course of the 19th century, mostly via natural history museums, which collected and displayed "the natural world" for a range of publics as the U.S. itself gradually took shape – acquiring and remaking the "wilderness" landscapes of the New World into a new U.S. nation-state. This chapter examines a range of 19th century U.S. natural history museums and their changing stakeholders and exhibitionary conventions, in order to analyze museums' shifting patterns of science boundary-work over time. It examines the shifting boundary between publics and scientists at different types of museums, particularly changes that accompanied the professionalization of science and attempts to demarcate "amateur" from "professional" science. Through their discursive and material exhibitionary practices, 19th century U.S. science museums participated in drawing cultural cartographies of science (Gieryn 1999) to map *where*, *how*, *why, by whom* and *to whom* credible scientific claims were made – or not.

This chapter also examines the changing significance of geography in framing "science" at natural history museums, in terms of museums' collection-building as well as exhibitionary conventions such as habitat dioramas, *lusus naturae*[9] ("freaks of nature") and taxonomic displays of specimens in glass cases. It situates this analysis in the context of the U.S.' transition from an early agrarian republic to an urban-industrial nation-state spanning the continent, in order to consider relations between natural history museums' internal spatial orders and their external spatial orders – including the "front stages" and "back stages" of museums' science displays. In this regard, the analysis takes a cue from Goffman (1959) and Hilgartner (2003), as well as from Knorr Cetina's approach to laboratories (1999), analyzing science museums as "*relational* units that gain power by instituting *differences* with their environment" (Knorr Cetina 1999: 44; emphasis in original).

Ultimately, this chapter argues that 19th century U.S. natural history museums institutionalized an increasingly professionalized cultural cartography of science, which buttressed a particular (Western) conception of "civilization." Thus 19th century U.S. science museums purportedly represented not only scientific knowledge, but civilized spaces of "rational amusement." This chapter also argues that specimens deemed *lusus naturae* were the flipside of this boundary-work; they did not fit smoothly into civilized spaces of rational amusement. *Lusus naturae* represented non-Westerners, lower-class publics with "vulgar" tastes, or anomalous entities outside the "natural order" of scientific intelligibility and of respectability. Moreover, the professionalization of science led to boundary-work obscuring the continuities between vulgar and respectable, "civilized" exhibitions. This science boundary-work was intertwined with but distinct from the separation of high-brow and low-brow culture in general, analyzed by DiMaggio (1982) and others[10]. Meanwhile, with the gradual naturalization of

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[9] A Latin phrase variously translated as "sports of nature," "jokes of nature" or "freaks of nature."

[10] The terms "low-brow" and "high-brow" actually derive *not* from class-based social divisions, but from racialized divisions between "civilized" versus "primitive" peoples. According to Lawrence Levine, these terms "were derived from the phrenological terms 'highbrowed' and 'lowbrowed,' which were prominently featured in the nineteenth-century practice of determining racial types and intelligence by measuring cranial shapes and capacities. A familiar illustration of the period depicted the distinctions between the lowbrowed ape and the increasingly higher brows of the 'Human Idiot,' the 'Bushman,' the 'Uncultivated,' the 'Improved,' the 'Civilized,' the 'Enlightened,' and, finally, the 'Caucasian,' with the highest brow of all." (Levine 1988: 222)

Western urban-industrial life, the cultural problem of "civilizing the machine in the garden" was looming – a problem that increasingly class-based discourses of rational amusement would not address. Tracing historical changes in science boundary-work at 19th century natural history museums provides insight into broader social and cultural tensions during a period of U.S. nation-state building, European and American colonialism, scientific specialization and professionalization, and the construction of an urban industrial order. It also underscores that science has never been pure, but rather embedded in history, society, culture and geography (Shapin 2010).

Rational Amusement,* Lusus Naturae *& Conventions of Public Science Exhibition

Before delving into pivotal 19th century U.S. science museums, it is helpful to introduce the general discourse of "rational amusement" invoked by science museums throughout the century, particularly in relation to public exhibition. In brief, the educational discourse of rational amusement, sometimes used synonymously with "rational recreation," sought to balance instruction and enjoyment. It was a cultural outgrowth of Enlightenment thinkers' emphasis on individual reason and free will, and resonated especially with Jean-Jacques Rousseau's educational philosophies in *Emile*. Museum founder Charles Wilson Peale, among others, attributed the doctrine of rational amusement to Rousseau, and held that education should take place in a framework of freedom and firsthand experience of nature, rather than a canon of assigned books.[11]

A fundamental pedagogic practice associated with rational amusement was the use of object lessons – offering students material objects and concrete specimens as learning aids, rather than abstractions and texts. This practice translated readily into a science museum context, with its emphasis on material culture. In such a framework, discovery was to happen organically, with learning and reason guided by what each person found intriguing to engage, rather than through the force of coercive discipline. Yet rational amusement did not encompass indulging in mere entertainment or recreation; education and amusement could and should be combined. However, just what constituted rational education versus mere entertainment was contested.

While rational amusement was open to interpretation, one consistent theme was the significance of "order," particularly taxonomic order. Both Linnaean taxonomy and the hierarchical taxonomy of the Great Chain of Being were thought to order the natural world in ways conducive to rational amusement. Advocates of rational amusement emphasized exposure to taxonomically ordered regularities, rather than anomalies, because encounters with regularities were supposed to reveal the order and rationality of nature – the laws of nature. Object lessons associated with rational amusement were to feature representative specimens and artifacts, not one-offs or freakish curiosities considered *lusus naturae*. Such anomalies seemed to fall outside of the purportedly rational natural order and to provide only frivolous titillation without a higher rational purpose. Their liminal status – the ambiguity of how to classify them in broader taxonomies – symbolically threatened intertwined natural and social orders. In contrast, the classification of species by taxonomists represented an advancement of scientific knowledge about the natural world and its order. Taxonomic classification provided the basis for what became known as biological systematics, or analyzing relationships among living things,

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[11] As Rousseau writes in *Emile*, "Our first masters of philosophy are our feet, our hands, our eyes. To substitute books for all that is not to teach us to reason. It is to teach us to use the reason of others. It is to teach us to believe much and never to know anything." (Rousseau 1979: 125)

including the evolutionary trajectories of species and ecosystems. So while Linnaean taxonomy and the Great Chain of Being were exhibitionary conventions deemed compatible with rational amusement, *lusus naturae* and other non-taxonomic displays, such as habitat dioramas, seemed difficult to subsume under a discourse of rational amusement – especially for museums seeking legitimacy as scientific institutions. These precepts were especially popular among late 19th century middle and upper middle classes, who tended to characterize amusement alone as "vulgar" and lower-class (Barber 1980: 123). The Table 1 summarizes core aspects of rational amusement and implications for science museums' exhibitionary practices.

Rational Amusement Pedagogic Elements: Practices and Discourses	***Core Exhibitionary Conventions of Rational Amusement***	***Direct Challenges to Exhibitionary Conventions of Rational Amusement***	***Liminal Exhibtionary Practices: Possible Challenges to Exhibitionary Conventions of Rational Amusement***
Practice: Object Lessons – pedagogy of material culture and firsthand experience, rather than abstractions and books	Regularities: taxonomically ordered artifacts and specimens; e.g.: Linnaean taxonomy, Great Chain of Being	Anomalies, freakish curiosities, *lusus naturae*	Habitat dioramas, including recreated wilderness landscapes
Discourse: Enlightenment discourse, emphasizing individual reason and free will	The natural world as orderly and rational; the new U.S. social order based on the "laws of nature"	Anomalies, freaks and *lusus naturae* as outside the natural order	Suspicion of images and sensuality in relation to reason; perception of wilderness as heathen, uncivilized, chaotic

Table 1: Rational Amusement Exhibitionary Practices and Discourse

Significantly, there were multiple, yet patterned types of *lusus naturae* – or bases on which something or someone might be characterized as *lusus naturae* in the 19th century. The commonality shared by *lusus naturae* lay not in their essential characteristics, but in their perceived challenge to established orders, whether the natural orders of scientific knowledge or social orders. According to Robert Bogdan in his classic sociological study of freaks (Bogdan 1988), in the 18th and 19th century "there developed an important and revealing, albeit blurry and noninclusive, distinction between two types of exhibits" (Bogdan 1988: 6) of anomalous beings: 1) creatures and people born with birth defects, such as two-headed calves and Siamese twins; and 2) non-Western creatures and peoples. Bogdan emphasizes that the blurriness of these categories reveals both the rudimentary state of scientific knowledge of the natural world and the Western cultural biases of scientists and Anglo-American publics, who were uncertain about people of unknown "races," as well as unfamiliar animals, such as giraffes. As Bogdan writes of this era's displays:

> As explorers and natural scientists traversed the world, they brought back not only tales of unfamiliar cultures but also specimens of distant wonders. Tribal

> people, brought to the United States with all the accoutrements of their culture out of context, stimulated the popular imagination and kindled belief in races of tailed people, dwarfs, giants, and even people with double heads (Clair 1968) that paralleled creatures of ancient mythology (Thomson 1968). (Bogdan 1988: 6)

Thus, especially before the late 19th century, "debates raged among scientists and laypersons alike as to whether a particular exhibit represented a new species or was simply a *lusus naturae*." (Bogdan 1988: 6-7) Both scientists and showmen, such as P.T. Barnum, sought to leverage such controversies to attract public attention. "Scientists…who did not then have the status they do today, gained visibility and authority by serving as 'experts' in curiosity controversies" (Bogdan 1988: 27). By the end of the 19th century, however, professionalizing scientists began to claim exclusive legitimacy for their understandings of the natural world via fields such as endocrinology, genetics and anthropology. Teratology – literally, the "study of monsters" – attempted to establish medical and scientific classifications for *lusus naturae* (Bogdan 1988: 27), as a first step toward explaining them, rather than considering them evil omens or witchcraft. Meanwhile interest in such *lusus naturae* became associated mainly with lower-class publics,[12] who were increasingly deemed illegitimate commentators on the natural world, as analyzed further in the rest of the chapter.

Peale's Museum: Civilizing Science in an Agrarian Republic Bordering "Wilderness"

Peale's Philadelphia Museum, the most notable of the first U.S. science museums, was a rather accidental and idiosyncratic affair, especially in its early years. Started by painter Charles Wilson Peale, best known for his portraits of American revolutionaries, the museum came to feature not only natural history and ethnographic specimens, but also paintings, mechanical models and miscellaneous attractions, such as a magic lantern show. It began as an adjunct to a home painting studio and gallery, as more and more people came to view some mastodon bones that Peale had acquired – the foundation of his natural history collection. The museum encompassed a range of objects, practices and audiences that in later years would be thought of as distinct, relegated to different and more specialized institutions, embedded in new social hierarchies as well as "natural" and built environments. Its intended audiences included the scientific community as well as the public, at a time when the boundary between these groups was more ambiguous and porous than it became by the late 19th century, when science was more professionalized.

In the late 18th and early 19th centuries, it was not unusual for amateur naturalists such as Peale actively to take part in scientific dialogue, both in the new U.S. and abroad. Two weeks after opening his museum, Peale became a member of the American Philosophical Society, and "consulted with three of the most eminent American scientists before he began" (Orosz 1990: 45), including David Rittenhouse, astronomer and mathematician; Robert Patterson, professor of mathematics at the University of Pennsylvania; and Benjamin Franklin, founder of the American

[12] In contrast, Findlen emphasizes that *lusus naturae* were integral to Renaissance scientific invesigation and discourse: "Incorporating phenomena as diverse and seemingly unrelated as flowers, shells, seahorses, fossils, giants, unicorns' horns, loadstones, and zoophytes, many Renaissance naturalists considered lusus naturae to be the key to an efficacious reading of the book of nature. Concomitantly lusus scientiae evidenced man's ability to match nature's complexity with his own artifice" (Findlen 1990: 293). Over the course of the Enlightenment, however, new generations of scientists increasingly marginalized *lusus naturae* and framed them as deviant anomalies, irrelevant to the broader scientific enterprise.

Philosophical Society. In other words, Peale's Museum was in many ways a generalist institution, in multiple senses of the word: an institution devoted to a broad array of things and knowledge, founded by a painter and amateur naturalist, for general scientific and public audiences, before the "old natural history" fragmented into geology, zoology, and more specialized life science disciplines. The museum was not yet part of the more specialized, systematized, supposedly rationalized world also taking shape in the early 19th century.

Despite these generalist orientations, Peale and his contemporaries in Philadelphia, including President Thomas Jefferson, were highly conscious of certain lines of demarcation in their world. First and foremost, they were conscious of the newly established borders of the U.S., which at that time encompassed only the thirteen initial colonies. These colonies – insurgent states joined together in federation – amounted to a strip of territory hugging the Eastern seaboard, while the vast majority of what would become the U.S. was still unexplored, unmapped and unsurveyed by Europeans, a "new world." Peale's Museum and other natural history museums would seek to inventory and understand this natural world to the West, which Europeans generally thought of as "wilderness." While different thinkers projected disparate meanings onto this wilderness, they tended to view it as opposed to the civilization that Euro-American elites aspired to and claimed for the new U.S. This was true especially in Philadelphia, the original U.S. capital and the country's most cosmopolitan city of the day.

This vast expanse of "the new world" was not incidental but central to the constitution of both U.S. national identity – including its exceptionalist aspects – and early 19th century natural history. For natural history investigation in Peale's day was intertwined with territorial exploration. As Coleman wrote, "Our ancestors came to live in a new world when science was still young. Minerals, plants, and animals they collected studiously – commencing with the plants – to find out what they were..." (Coleman 1939: 221). In this vein, Peale and his contemporaries discussed the Western wilderness as a source of scientific discovery, giving the U.S. an edge over Europe in the potential for future contributions to natural history. As Peale wrote in a 1792 letter "To the Citizens of the United States of America":

> With harmony all little things become great: all the splendid Museums of the great European nations have risen from the foundations laid by individuals. America has in this a conspicuous advantage over all other countries, *from the novelty of its vast territories*. But a small number is yet known of the amazing variety of animal, vegetable and mineral productions, in our forests of 1000 miles, our inland seas, our many rivers, that roll through several states, and mingle with the ocean…Mr. Peale means personally to solicit the assistance of gentlemen whose regard for science is well known. (as quoted in Carbonell 2004: 130; emphasis in original)

In other words, this early 19th century paradigm of natural history investigation went hand in hand with the exploration of uncharted wilderness landscapes – and the territorial incorporation of the U.S. itself. The Lewis and Clark expedition, for example, collected specimens that later went to Peale's Museum. It was the first in a series of government expeditions and state surveys that would contribute not only to state-building but also to natural history collection-building. Indeed, Peale, Jefferson and other elites of the day saw the enterprises of natural history and nation-building as intertwined, and Peale's Museum collected specimens and artifacts to preserve as the patrimony of the new U.S., rather than having them be transported to European museums. As Peale put it, "'…too many rare and valuable things have already been sent & are still daily sending to the other side of the Atlantic'" (Peale as quoted in Orosz 1990: 53). Many thought of these vast expanses of "the new world" as quite literally bequeathed to the U.S. by God, not merely patrimony but divine patrimony. They viewed the Western wilderness as both a challenge and a divine opportunity for the advance of civilization, including science, through the U.S. nation-state. As Peale described his exhibitionary intentions, "[The museum] would 'present to the American as well as the European World, an evidence of our progress in the department of science, whose successful cultivation has always been a characteristical mark of an advanced civilization" (Orosz 1990: 54). In other words, Peale and his contemporaries articulated a particular cultural framework for viewing the natural world and science, in which scientific knowledge buttressed Western conceptions of civilization, articulated with U.S. nationalism.

This view of national patrimony assumed the domestication and utilization of "nature's nation" (Opie 1998), however – the civilized cultivation of the natural world that European settlers perceived Native Americans, content to live in a heathen wilderness, to have neglected. To Europeans, natural history investigation (often intertwined with religious motivations) and commercial exploitation of the natural world were both forms of civilizing this wilderness. Thus natural history museums and their collections, including Peale's, while on the one hand framed in purportedly transcendent scientific terms, were simultaneously infused with moral and practical meanings about relating to nature, including its uses. As one early 19th century lyceum movement leader said of natural history collections, emphasizing the association between museum specimens and national economic development, "if placed 'before legislators and others, specimens of their own productions and a knowledge of their own resources in the mineral kingdom, by which industry would be encouraged and individual and public wealth and prosperity increased, they would support the creation of museums'" (Henson: 39). In other words, natural history was in many respects a utilitarian science. Natural history collections might be removed from commercial circulation in a "scientific" space, but remained articulated with national and commercial framings of the natural world, intertwined with narratives of Western civilization. Ultimately, through their identification and mapping of natural resources, state natural history surveys both built up museum collections and helped to pave the way for industrialization, raising the on-going cultural dilemma of "civilizing the machine in the garden," or balancing conservation and exploitation of nature. Thus inside the museum, rational amusement entailed educating museum visitors and providing them with uplifting, rational encounters with "the natural world," while beyond the museum the overarching improvement goal in the early national period was to "convert the howling wilderness into a domesticated agricultural landscape" (Opie 1998: 190).

The multifaceted meanings of natural history collections were reflected in Peale's intended museum audience of both scientists and publics – including farmers, merchants and mechanics (Conn 1998: 35). Peale argued that natural history collections could be sources of both practical knowledge and moral uplift, especially in a nation where he, like Jefferson, deemed agriculture "the most important occupation" (Sellers 1980: 102). As Peale put it, "The farmer ought to know that snakes feed on field mice and moles, which would otherwise destroy whole fields of corn…To the merchant, the study of nature is scarcely less interesting, whose traffic lies altogether in material either raw from the stores of nature or *wrought* by the hand of ingenious art…The mechanic ought to possess an accurate knowledge of many of the qualities of those materials with which his art is connected" (Conn 2010: 210). These practical objectives accompanied the museum's scientific goals and aspirations to demarcate a "civilized" space in the new republic. Peale also valued engagement with and the approval of recognized scientists, as mentioned above. In sum, at an institutional level, Peale's Museum was a nationally oriented venture that aspired to reach varied publics as well as the diffuse and relatively non-professionalized scientific community, in a period when the distinction between amateur and professional scientists was not yet entrenched. It did so in a still small agrarian nation-state perceived as facing a vast, unknown and uncivilized wilderness of natural abundance.

Taxonomic Orders & **Lusus Naturae*:*** ***Science Boundary-Work at the Margins of Rational Amusement***

Moving now to the exhibitionary level, what were the internal spatial and material cultural practices, through which the museum attempted to constitute a civilized, enlightened, rational space for science? How did these practices embody and negotiate broader social tensions, as discussed above? How did these museum practices participate in science boundary-work in the process? Here I focus on Peale's Museum as it was constituted in Philadelphia's State House. There it took the form for which it is best known in his most famous self-portrait, standing before a raised curtain and ushering the viewer into his museum's Long Room, with its rows of cabinets and specimens. It is a room that embodies order – taxonomic, classificatory order. On the one hand, Peale's collections were labeled and arranged according to Linnaean taxonomy, as Peale described, "Having formed a design to establish a MUSEUM, by a Collection, Arrangement, and Preservation of the Objects of Natural History, and things useful and curious, in June 1785, he began to collect subjects, and to *preserve* and *arrange* them in the Linnaean method …" (Charles W. Peale, Jan 13, 1792; emphasis in original). This Linnaean logic operated at the levels of artifacts as well as collections and the museum space as a whole. In the State House location, for example, "Linnaeus's classification of animals is framed in the Rooms. The name of each genus and various specimens numbered, and the Latin, English and French names placed over each case…" (Sellers 1980: 159). Peale's Museum thus instantiated multiple levels of classification and taxonomizing (Jordanova 1989).

In addition, Peale's Museum exhibited distinct "races of mankind" (Sellers 1980: 92) and organized artifacts in a racialized "Great Chain of Being." Portraits of American revolutionaries and other contemporary elites hung near the ceiling, while stuffed birds and other creatures, as well as ethnographic artifacts and Native American wax figures, were arrayed below behind glass. Peale aspired for this arrangement "to shew a gradual link in the natural connecting chain" (Sellers 1980: 111), or Great Chain of Being, opening a Deist "Book of Nature" to visitors. Throughout the museum, these spatial and material cultural practices conveyed a taxonomically ordered, systematized, rationalized natural world. They suggested that such order in general was "natural." This world was in many ways a counter-point to European ideas about the Western wilderness beyond museum walls, as well as to ideas about the purportedly less civilized races of mankind who dwelled there. In contrast to this wilderness, the museum marked off a taxonomic space for science, a "civilized" space of order that appeared harmonious, rather than chaotic or laden with conflict. As Christopher Looby writes in an article analyzing the cultural dimensions of taxonomic practices of Peale, Thomas Jefferson and the naturalist William Bartram, "In the thought of cultural leaders of the early national period, there is a kind of automatic metaphorical exchange between images of natural order and ideas of social and political order. The period is one of cultural 'constitution' in a broad sense…" (Looby 1987: 253). The museum's walls, spaces and specimens participated in this science boundary-work, demarcating natural knowledge as taxonomically ordered and Euro-American, informed by an Enlightenment cultural cartography of science.

The museum also contained a range of objects and displays that did not fit smoothly into this taxonomic organization or the conventions of rational amusement that Peale's Museum aspired to uphold. As Charles Coleman Sellers writes, in discussing Rousseau's influence on Peale, "[T]he concept of a museum of natural science as an educational experience for everyone, its effectiveness based upon…'rational amusement,' this was the Rousseau doctrine of education as a sacred mission to be accompanied and accomplished by the enjoyment of life. This was the chain of flowers leading toward a rebirth of civilization in free America" (Sellers 1980: 26-27). Yet Peale's Museum contained *lusus naturae*, disparaged by the doctrine of rational amusement. For example, Peale's collections included a five-legged cow, a two-legged calf, and the finger of a murderer. Peale's Museum contained not only representative specimens and taxonomic series ordered according to Linnaean nomenclature, in other words, but anomalous and sensationalist artifacts, the display of which seemed to serve no such higher purpose as "a rebirth of civilization in free America."

Peale's inclusion of *lusus naturae* in his museum was due to both his acceptance of public donations, as well as his interest in public attendance. For many people, such *lusus naturae* and freakish curiosities were the main reason to visit a museum, the regularities of the "Book of Nature" aside. Peale was aware of this, though he acknowledged the tension between such unusual artifacts and the rational amusement to which he aspired. According to Sellers, "*Lusus naturae*, [Peale] explained over and over, were exceptions to the rule, objects for a museum to keep but only show upon reasonable request" (Sellers 1980: 42). Though Peale claimed that he displayed the cow only due to its size (it could not easily be stored away), in general he believed that "[d]eviations from the normal must be 'received with caution' and stored separately" (Sellers 1980: 60). In other words, Peale managed the tension between *lusus naturae* and rational amusement through selective access to and display of such "anomalous" artifacts. This helped him to maintain public interest as well as respectability in the relatively non-professionalized scientific community of the day, which he seems to have achieved. According to Sellers, "James Hardie's *Philadelphia Directory and Register* (1794) gave the Museum top place among the city's scientific institutions, extolling it for beauty and taste and also praising Peale's discretion in keeping disquieting *lusus naturae* out of sight" (Sellers 1980: 70). Museum practices to contain *lusus naturae* were central to its science boundary-work and to attempts to maintain both scientists and publics as audiences. The relative lack of scientific professionalization also meant that the evidentiary criteria and gatekeepers for "scientific" legitimacy were less clear and stringent.

In addition to its taxonomic ordering practices, another way in which Peale's Museum framed "the natural world" and engaged in science boundary-work in its exhibitionary practices was to maintain a "frontstage" and "backstage," in Erving Goffman's sense of these terms (Goffman 1959). The taxonomic order that characterized his museum's Long Room was a kind of frontstage, while unclassifiable, unseemly *lusus naturae* were kept backstage, viewable on request. These practices served to exclude *lusus naturae* from the museum's official self-presentation, helping it to maintain both scientific credibility and interest by wider audiences. According to Orosz, "This compromise between the popular and the scientific, tenuous as it was, kept the museum both profitable and [scientifically] respectable for more than forty years" (Orosz 1990: 45). At the same time, Peale's approach to rational amusement meant distancing the museum from the ever more popular commercial museums and freak shows that reveled in the "deviant" in the antebellum period, as discussed further below.

Early habitat dioramas were another feature of Peale's Museum that subverted its overarching taxonomic organization and problematized the spatial logic of constituting a space for science set apart from wilderness. At the museum's initial location, for example, visitors encountered at the entrance a kind of early habitat diorama, featuring a stuffed American buffalo set in a recreated landscape that included a pond and forest full of stuffed birds, reptiles, fish and mammals (Sellers 1980: 69). At the museum's later State House location, there were also rudimentary habitat dioramas, in the form of birds and small mammals in glass cases against painted backgrounds. Yet habitat dioramas' painted, recreated landscapes, relatively lacking in taxonomic organization, seemed to some observers closer to art or "mere amusement" than scientific displays or rational amusement. Such techniques were also not legitimated by precedents at museums in Europe, which the new U.S. sought to emulate. All this led Peale to defend his museum's habitat dioramas by saying:

> It is not customary in Europe, it is said, to paint skys and landscapes in their cases of birds and other animals, and it may have a neat and clean appearance to line them only with white paper, but on the other hand it is not only pleasing to see a sketch of landscape, but by showing the nest, hollow, cave or a particular view of the country from which they came, some instances of the habits may be given. (as quoted in Sellers 1980: 28)

It was important to Peale to emphasize the scientific rationale for these pleasing paintings and recreated wilderness landscapes. Otherwise, like *lusus naturae*, they threatened to subvert the taxonomic order associated with rationally ordered scientific knowledge. Habitat dioramas thereby problematized the boundary between scientific knowledge, on the one hand, and non-scientific knowledge or mere entertainment, on the other. Moreover, if one purpose of the science museum was to differentiate its orderly natural world from the perceived chaos of wilderness, then habitat dioramas partly let wilderness back in – domesticating wilderness in a civilized cultural space. Thus, while set within an overarching taxonomic organization, habitat dioramas at Peale's Museum asserted a limited place for art and wilderness landscapes in representing scientific knowledge – as long as the former were subservient to the latter. Habitat dioramas blurred – at least to some extent – the boundary between science and art, as well as the space of the museum and landscapes beyond. Later antebellum science museums, however, more exclusively oriented toward research and professional scientists, would forego the use of habitat dioramas altogether. This neglect left habitat dioramas to be "rediscovered" – and newly contentious – in the later 19th century, by civic natural history museums oriented toward both research and public exhibition that sent out their own collecting expeditions. By this time, the wilderness would also be less threatening; indeed, the conservation movement would recognize wilderness itself as threatened.

Gentlemen's Scientific Societies:
Rationality & Discretion Amidst an Increasingly Domesticated Wilderness

Beyond Peale's Museum, the U.S. gradually began developing an infrastructure for scientific research in the early 19th century, as "gentlemen scientists" – usually with other, patrician professions providing them with sufficient resources – founded learned societies, including natural history societies. These new scientific societies, unlike Peale's Museum, were devoted primarily to pursuing members' research interests. They would engage in new patterns of science boundary-work in the process. Foremost among these new natural history societies was the Academy of Natural Sciences of Philadelphia, formed by gentlemen scientists[13] in 1812. Given its primary mission of supporting scientific research, the Academy did not open a public natural history museum until 1826, since "a display of objects had not seemed central to that purpose [of scientific research]" (Conn 1998: 38). This natural history museum, however, in being attached to a society oriented primarily toward scientific research, was still a relatively sequestered place. For example, its first public exhibit hall was open to the public only "two half days in every week for citizens" (as quoted in Allmon 2004: 255) and only if they brought in hand a ticket signed by an Academy member. This policy contrasted with Peale's Museum, where "the entrepreneur needed to make his holdings as accessible as possible" (Kohlstedt and Brinkman 2004: 10).

In addition, collections at the Academy were regarded primarily as the private property of individual Academy members, and only secondarily as the property of the museum as a whole. Such an arrangement was typical of contemporary natural history societies. As Kohlstedt and Brinkman write, "Collectively, the societies of naturalists in Charleston, Philadelphia, Boston, New York City and elsewhere arranged to rent or purchase rooms or even a building where each member might put a cabinet on display…For decades [the Philadelphia Academy's] members met and held their specimens in a private space" (Kohlstedt and Brinkman 2004: 10). So while Peale limited access to specific exhibits and specimens, these societies limited public access to their collections overall. With their emphasis on research as the primary rationale for natural history collections, museums as a whole became a relatively backstage affair. Not only were *lusus naturae* not featured, they were a moot point.

Exhibitionary approaches such as habitat dioramas also did not appear at all at the early Philadelphia Academy of Sciences or similar research-oriented institutions, such as the Boston Society of Natural History, founded in 1830[14]; the California Academy of Sciences, founded in 1853[15]; or the Museum of Comparative Zoology at Harvard, founded in 1854.[16] Their mission was to sort out and make sense of the natural world via taxonomizing, not attract public interest or represent scientific knowledge through aesthetic means. The Smithsonian's natural history museum,[17] though founded in 1846 under more public auspices and premises, was until 1857 also devoted to "specimens…collected solely to serve as materials for research. No special effort was made to exhibit them to the public or to utilize them except as a foundation for scientific description or theory"[18] (Farrington 1915: 204). These museums' more rationalized exhibitionary conventions left the habitat dioramas of painter-naturalist Peale to be revived only

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[13] One of its foremost members, and president between 1817 and 1840, was William Maclure, "the father of American geology." (Henson: 40)

[14] The Boston Society of Natural History was another leading institution of scientific research in the early U.S., again founded by gentlemen scientists, who shortly thereafter began to publish the *Boston Journal of Natural History*. Society members also took part in the initial botanical and geological surveys of Massachusetts.

[15] The California Academy of Sciences was founded by "seven prominent citizens of San Francisco for the purpose of 'a thorough survey of every portion of the State and the collection of a cabinet of her rare and rich productions." (Allmon 2004: 256) The Academy did not open a public museum until 1874, though earlier it apparently shared specimens with public school students.

[16] The Museum of Comparative Zoology at Harvard was founded by influential Swiss émigré naturalist Louis Agassiz.

[17] What became the Smithsonian's Natural History Museum was initially known as the United States National Museum.

[18] From 1857 until 1876 specimens were publicly exhibited, but only on a limited basis, when "convenient." (Farrington 1915: 204)

later in the 19th century. In these ways, antebellum natural history museums after Peale's Museum tended to establish conventions for exhibiting the natural world that were consonant with a "rationalized" rational amusement, more firmly anchored in scientific research as a primary objective. Through their spatial and exhibitionary practices, these natural history collections participated in science boundary-work that emphasized the distinctive, gentlemanly status of scientific inquiry and its separation from broader publics, as well as popular forms of display. They represented the burgeoning professionalization of science in the U.S. that accelerated throughout the 19th century, as science became institutionalized in exclusive occupational groups with bodies of abstract knowledge through which they claimed jurisdiction to particular tasks, issues and cases (Abbott 1988: 8), such as natural history systematics. At the same time, there were overarching continuities between Peale's Museum and the Philadelphia Academy of Sciences and similar scientific societies, in the meanings that framed natural history collections as civilized depositories vis-à-vis wilderness.

Urban Dime Museums Revel in **Lusus Naturae***:* *P.T. Barnum's American Museum as Prototype*

Commercial dime museums also emerged during the antebellum period. Dime museums were devoted first and foremost to profits and hence to attracting broad publics, rather than to scientific research. They were part of the era's burgeoning urban consumer culture, including the amusement industry. Foremost among these antebellum dime museums was Barnum's American Museum in New York (1841-1865), which established the prototype of the dime museum in the U.S., predating Barnum's circus career. Meanwhile Peale's sons Rubens and Franklin, who had taken over management of their father's Philadelphia Museum, "failed to chart a course between an emerging scientific professionalism and the circus showmanship of P.T. Barnum" (Henson 2004: 38). Attempts by Rubens and Franklin to establish similar, spin-off museums in Baltimore and New York also failed to navigate the changing scientific and cultural terrain, and ultimately folded. Ironically, when Peale's Museum finally closed in 1849, Barnum ended up purchasing many of its specimens. Barnum thus borrowed from Peale's exhibitionary conventions both literally and figuratively. However, while Philadelphia's Academy of Natural Sciences rationalized its museum displays compared with Peale's Museum, excluding *lusus naturae* and habitat dioramas, Barnum's American Museum would build on and amplify these popular display conventions, alongside more conventional natural history exhibits. In a sense, Peale's dual objectives of scientific credibility and popularity became fragmented and institutionalized at different types of museums in the antebellum period – research-oriented museums and dime museums. As one early 20th century commentator put it, "Many of these early institutions [such as Peale's Museum and its contemporaries] contained really valuable specimens, but they also contained a large proportion of objects that now find a place by themselves in the well-known dime museums, which in a way are their direct, if degenerate, successors" (Lucas 1917: 84).

Barnum's American Museum began taking shape in 1841 when Barnum purchased Scudder's American Museum in New York City, then a competitor of Peale's New York Museum (which had been operated by Peale's son Rubens until 1830, when he lost it to creditors). John Scudder Sr. had been an amateur naturalist and taxidermist, who acquired the capital to purchase his museum by working as a sailor (Dennett 1997: 17). When Barnum bought the museum, it was operated by his son, John Scudder Jr., who had added "variety acts, minstrel shows, and displays of freaks" to the museum's repertoire. At the time, many proprietary U.S.

museums such as Scudder's were struggling financially, trying to maintain popularity and respectability while turning ever more toward an emphasis on amusement. Barnum took these trends to new heights, using his knack for showmanship to establish his museum as an entertainment destination for visitors from near and far. Barnum changed exhibits frequently and featured freak shows in the museum's lecture hall, including acts that would become part of the American pop-cultural pantheon of the 19th century, such as General Tom Thumb.

Barnum intended these displays to appeal to publics ranging from families to visiting dignitaries, striving for cultural legitimacy as well as profits, if not scientific legitimacy on the terms of gentlemen scientists and the gradually professionalizing scientific field. Summing up Barnum's complex social and cultural positioning of his museum, dime museum historian Andrea Stulman Dennett argues that Barnum "wanted his museum to be respectable, and he attempted to reject anything that might be repugnant to a conservative Victorian audience, but his 'operational aesthetic'…was not to instruct but to amuse"[19] (Dennett 23). Located across the street from the Astor House, then the city's most prestigious hotel, and near City Hall, Barnum's museum was an institution at the heart of city life. As Bogdan puts it, in its own day, "The American Museum was not a sleazy operation on the fringe of Victorian America; it was, rather, quite fashionable and most legitimate" (Bogdan 1988: 32). Indeed, Henry David Thoreau reportedly enjoyed the museum's aquarium, commenting "The sea-anemones were new and interesting to me" (Betts 1959: 355). According to Betts, by mid-1850s "the American Museum was accorded the reputation of being 'one of the largest and best arranged collections in the known world.' Few farmers from the hinterlands or dignitaries from abroad (from Thackeray and Dickens to the Prince of Wales and the 'Japanese Ambassadors') ever missed this new national landmark" (Betts 1959: 355). Barnum's American Museum was a standout in the expanding urban amusement industry of the day, in the U.S.'s leading industrial hub, at a time when the country's identity increasingly hinged on urban-industrial life rather than agriculture, in contrast to when Peale's Museum was founded.

As for its collections, an incredible eclecticism characterized Barnum's museum, spanning both *lusus naturae* and prosaic natural history specimens. On the one hand, Barnum's museum contained many conventional – and conventionally credible – natural history displays. Though no comprehensive inventory of its collections was ever compiled (Saxon 1989: 134), the museum published various guidebooks over the years, providing overviews of its exhibits. Natural history specimens – from insects and mammals to rocks and fossils – made up the core of its collections. These specimens included taxidermy and living collections akin to those at more scholarly museums, aquaria and zoos. In the 1850s incarnation of Barnum's museum, for example, the second floor featured a large hall known as the "Second Saloon," which featured numerous natural history specimens in floor-to-ceiling glass cases – not unlike Peale's Museum. These included "Red-headed Ducks of North America," as well as "African Ostrich and Ant Eater" (Dennett 1997: 32). Next to this hall, a similar saloon featured ethnographic artifacts as well as taxidermy birds. Also adjoining the Second Saloon was an aquarium, featuring both fish tanks and glass cases with preserved fish specimens and shells. On the third floor, taxidermy mammals such as a giraffe and a kangaroo were displayed. Barnum built up the American Museum's natural history collections over decades of traveling the world, while also supplying specimens to more conventional natural history museums oriented toward scientific research

[19] Here Dennett borrows a phrase from Neil Harris (1973).

(Betts 1959). In 1876, Barnum was among those whom the Smithsonian Institution invited to place a bust in the museum's gallery of men distinguished for promoting the natural sciences.

On the other hand, conventional natural history collections and Linnaean labeling notwithstanding, given Barnum's emphasis on public attendance, Barnum's museum and later dime museums included a plethora of displays that reveled in the anomalous and "freakish," rather than keeping *lusus naturae* out of sight. Such curiosities were a huge public draw, and Barnum attempted to exploit this appeal with ever more bizarre displays as well as live shows. These exhibits often shared space with more conventional natural history displays, meaning that space in Barnum's American Museum was less rationalized according to Linnaean taxonomy than in Peale's Museum. For example, the ethnographic artifacts and stuffed birds in Barnum's Third Saloon were accompanied by an exhibit featuring freak show performer Tom Thumb's clothing as well as a collection of famous autographs (Dennett 1997: 32). Then there was "The Happy Family" on the museum's top floor; this exhibit featured a cage containing more than sixty animal species, each supposedly "the mortal enemy of every other," yet miraculously living in harmony in the cage (Dennett 1997: 33-34). Thus Barnum's American Museum combined *lusus naturae* with more conventional, rationally amusing instruction, its specimens often overlapping with natural history displays at non-commercial museums oriented toward science.

Yet Barnum not only highlighted *lusus naturae* that Peale had mostly put away; he actively concocted and manufactured anomalies – "humbugs." This was a line that neither Peale nor his more commercially oriented sons ever crossed. For example, in 1842 Barnum debuted the Fejee Mermaid, a creature fabricated from a mummified monkey's head attached to the body of a fish – one of Barnum's most infamous hoaxes. In so doing, Barnum played with the conventions of rational amusement beyond anything attempted or condoned at Peale's, reveling in *lusus naturae* to develop his trademark brand of playful deception, or "humbug." As Barnum described the Fejee mermaid in an 1842 advertisement, echoing Peale's claims to present the public with the Great Chain of Being:

> This animal was taken near the Fejee Islands, and purchased for a large sum by the present proprietor, for the Lyceum of Natural History in London, and is exhibited for this short period more for the gratification of the public than for gain. The proprietor having been engaged for several years in various parts of the world in collecting wonderful specimens in Natural History, has in his possession, and will at the same time submit to public inspection, The Ornithorhinchus, from New Holland, being the connecting link between the Seal and the Duck…with other animals forming connecting links in the great chain of Animated Nature. (Barnum 1855: 238)

Thus Barnum framed his concocted *lusus naturae* in the rhetorics of scientific discovery, rather than framing them as beyond the bounds of rationality and rational amusement – or as fraud, as did his detractors. Herein lies the crux of the controversy over Barnum's significance to science and the emerging field of science museums, particularly its changing patterns of science boundary-work with the professionalization of science.

To his detractors, Barnum merely ensconced his humbugs and other freakish exhibits in the rhetorics of science without credible substance, serving no rational end. He thereby became a lightning rod for accusations of charlatanism and pseudo-science, rather than merely a low-brow entertainer – though these forms of intellectual and social opprobrium were intertwined. Yet, as mentioned above, Barnum's contributions to science were also recognized, at least in the form of his conventional, rationally amusing natural history specimens. In part, this honor and the scientific value bestowed on Barnum's activities were possible because science was relatively unprofessionalized during the early and mid-19th century, with a wider array of participants contributing to the constitution of legitimated scientific knowledge and culture.

More interesting and complicated, however, including in relation to this professionalization of science and the scientific enterprise, are the status of Barnum's humbugs, such as the Feejee mermaid. As Barnum writes in *Humbugs of the World*, while distinguishing his own approach to and understanding of humbug from swindling and cheating, a man may be called a humbug "[n]ot because he cheats or imposes upon the public, for he does not, but because, as generally understood, 'humbug' consists in putting on glittering appearance – outside show – novel expedients, by which to suddenly arrest public attention, and attract the public eye and ear" (Barnum 1866: 20). This is precisely the kind of show-business in which Barnum engages in his museum, in the context of the growing urban consumer culture with its novel entertainments and advertisements. Barnum does not view those purporting to be scientists as removed from this milieu. As he writes, "Science is the pursuit of pure truth, and the systematizing of it. In such an employment as that, one might reasonably hope to find all things done in honesty and sincerity. Not at all, my ardent and inquiring friends, there is a scientific humbug just as large as any other" (Barnum 1866: 14). Barnum's humbugs are meaningful against this backdrop.

Given Barnum's distinctions between humbugs and swindling, and his understanding of the milieu in which he operated, contemporary Barnum scholars argue that he should not be understood as a straightforward deceiver engaged in propagating pseudoscience, but as presenting publics with perceptual games engaging their capacities to evaluate truth, including purported scientific truths (Cook 2001; Harris 1973). As Barnum advertised the Feejee mermaid in 1843:

> Engaged for a short time the animal (regarding which there has been so much dispute in the scientific world) called the *FEEJEE MERMAID!* positively asserted by its owner to have been taken alive [in] the Feejee Islands, and implicitly believed by many scientific persons, while it is pronounced by other scientific persons to be an *artificial* production, and its natural existence claimed to be an utter impossibility. The manager can only say that it [h]as such *appearance of reality* as any fish lying [in] the stalls of our fish markets – but [who] is to decide when *doctors* disagree. At all events whether this production is a work of *nature or art* it is decidedly the most stupendous curiosity ever submitted to the public for inspection. If it is artificial the senses [of] sight and touch are useless for *art* has rendered them totally ineffectual – if it is natural then all concur in declaring it *the greatest Curiosity in the World*. (as quoted in Cook 2001: 84)

In this case and other exhibits, Barnum's humbugs played with official scientific rhetorics that Peale had taken seriously. In his humbugs, Barnum entertainingly deployed the rhetorics of science and credulity in a way that highlighted the guesswork, contestation and interrogation of "the natural world" that were supposedly at the heart of science and available to all, even as professional scientists emerged and began to claim their own unique rationality and legitimacy.

Accepting the view of Barnum's detractors that his museum was unequivocally beyond the bounds of rational amusement and science would be to in some sense to reify "science" and *lusus naturae* – disregarding the cultural, historical and geographical contingencies of these categories. As science professionalized, it became harder for laypeople –

as *non*-scientists – to credibly contest such categories, particularly if they were themselves implicated by them. It also became more difficult for laypeople to underscore the continuities between popular exhibitions of *lusus naturae* and scientists' displays of the exotic in anthropology and other exhibitions. The categories of professionalizing science exercised growing infrastructural power over people and things, in other words (Bowker and Starr 1999). Barnum's irreverence toward science, even as it professionalized, and his willingness to play with rhetorics of scientific legitimacy via his humbugs arguably opened up a space for publicly contesting truth claims and perceptual games that began more constricted as "amateur" and "professional" science parted ways.

Late 19th Century Natural History Museums: The Victorian Rage for Order

In 1865 Barnum's American Museum, the U.S. archetypal dime museum, burned to the ground. While some mourned its passing, others publicly declared good riddance at its demise. This contingent saw an opportunity for New York to construct an American Museum truly worthy of the name and the city, as they saw it. As some Barnum detractors put it in an unsigned article that appeared in *The Nation* two weeks after the destruction of the American Museum:

> Barnum's Museum is gone at last…The occasional visitors to the city from the 'rural districts' will no longer yield to its irresistible attractions. The worst and most corrupt classes of our people must seek some new place of resort, and other opportunities of meeting one another…Let New York, then, create for itself an 'American Museum.' And let the thing itself be not unworthy of the name it rashly assumes. (*The Nation*, July 27, 1865)

This elite viewpoint supported the construction of a different kind of natural history museum, a more "respectable" and credible museum than Barnum's American Museum and other dime museums.

What organization and exhibitionary conventions would characterize such a natural history museum? How would it negotiate the terrain between the hermetic, scientifically oriented museums of universities and natural history societies, on the one hand, and the public exhibition-oriented dime museums such as Barnum's American Museum, on the other? One foreshadowing is in the words of Barnum's detractors:

> But there is another consideration…The more truly one loves a collection well arranged, the more he will be offended by a chaotic, dusty, dishonored collection. The more one loves the order and system of scientific enquiry, the more he will feel personally injured by disorder and lack of system among the materials of scientific enquiry…Without scientific arrangement, without a catalogue, without attendants, without even labels, in very many instances, the heterogeneous heap of 'curiosities,' valuable and worthless well mixed together… (*The Nation*, July 27, 1865)

Again, these late 19th century critics of Barnum viewed taxonomic ordering as central to respectable, credible, and rationally amusing exhibitions of "the natural world." As at Peale's Museum, this entailed the exclusion of *lusus naturae* from the museum space and regular collections of Victorian natural history museums. Anomalies, freaks and curiosities did not show the regularities deemed "scientific," revealing the supposed order of the natural world.

In the new urban-industrial social order, such *lusus naturae* had become associated with disreputable, working-class publics and passions. New standards of civility and decorum were emphasized in urban life (Kasson 1990). A “civilizing process” (Elias 1994) for displays of the natural world seemed to be called for, at least to some critics. Not only did dime museums attract the “worst and most corrupt classes of our people,” as Barnum’s detractors continued, curiosities and freaks, “pandered to the most foolish curiosity,” and “the most morbid appetite for the marvelous” (*The Nation*, July 27, 1865). By the late 19th century, new concerns with displaying the natural world had emerged at science museums, in the context of new urban-industrial publics and diversifying urban cultural landscapes. Taxonomic exhibitionary conventions were less oriented toward establishing a counter-point to an unexplored Western wilderness, as at Peale’s Museum. Instead, taxonomic exhibition helped demarcate respectable *urban* scientific culture from the disreputable, characterized by intemperate curiosity, suggesting undisciplined passions. Science boundary-work at museums became more solidly anchored in an urban-industrial social context.

The New American Museum of Natural History: Professionalizing Natural History as High Culture

The founding of New York’s American Museum of Natural History (AMNH) in 1869 represented the triumph of an alternative vision of an American Museum for New York, compared with Barnum’s earlier American Museum. The AMNH would be oriented toward both scientific research and public exhibition – toward producing new knowledge by professional scientist-curators, while displaying the more visually appealing manifestations of this knowledge for publics. The museum managed this combination in the increasingly specialized context of the late 19th century by reinventing the natural history museum as a form of urban high-brow culture, fusing the interests of both professionalizing scientist-curators and industrial elites. It would come to be thought of as a high-brow natural history museum, as opposed to a low-brow dime museum. Neither hermetically oriented toward scientific research nor emphasizing freakish curiosities to draw public interest, the AMNH instead established a model of the natural history museum as an urban civic institution oriented toward advancing and popularizing professionally respectable science, funded significantly by industrial elites. By the late 19th century, two of the U.S.’s leading natural history museums – New York’s AMNH and Chicago’s Field Museum – had been founded along these institutional lines.[20] These museums continue to be counted among the U.S.’s leading natural history museums.

Two related aspects of this professionalization of science were most important to late 19th century natural history museums: 1) the growing significance of universities, rather than amateur and gentlemen’s scientific societies, as sites of scientific research and training, spurring some older scientific societies to reinvent themselves to include public exhibition; and 2) the professionalization of science museum work and natural history curation, including through scientist-curators trained at university-based museums such as Harvard’s Museum of Vertebrae Zoology. Both dimensions of science professionalization contributed to boundary-work between scientists and publics at museums and beyond, and laid the groundwork for non-profit organizational forms, supporting both research and public exhibition, to be appealing not only to elite trustees but scientist-curators, as discussed further below.

First, by the later 19th century, there was a trend toward increasing specialization and professionalization of U.S. scientific research, particularly at universities, which displaced older

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[20] The other leading U.S. natural history museum is the Smithsonian’s Museum of Natural History, which developed based on collections from U.S. government expeditions, as discussed earlier.

scientific institutions. Amateur and gentlemen's scientific societies, such as the Boston Natural History Society, were less relevant to cutting-edge scientific debates as research became more institutionalized at university-based museums and labs. The BNHS, for example, was surpassed by Harvard's Museum of Vertebrae Zoology. In consequence, by the later 19th century, the BNHS and similar societies, such as the Philadelphia Academy of Sciences, increasingly emphasized public exhibition as a way to stay relevant and solvent. As Kohlstedt puts it, in the case of the BNHS, "As local educational institutions and nationally based scientific organizations developed by mid-century, the Society's visibility and functions eroded...Dramatic change or demise seemed the only alternatives" (Kohlstedt 1979: 391).

Given these institutions' beginnings as more hermetic, scientifically oriented research sites, however, they chose a conservative, high-brow path to public exhibition. They increasingly emphasized their museums and public display, but in the mold of high-brow civic culture, akin to the AMNH. The Smithsonian's natural history museum (then the U.S. National Museum) also followed suit in its exhibitionary conventions, shifting away from emulation of hermetic natural history society collections and toward ever more impressive public exhibition, while excluding *lusus naturae*.

By the late 19th century, therefore, science museum work and natural history curation had become more professionalized, rather than the avocation of amateur naturalists such as Peale or the gentlemen scientists who started the first scientific societies. University-trained scientist-curators – including museum-based paleontologists, botanists, zoologists and anthropologists – sought to demarcate their museums from disreputable natural history exhibitions, such as Barnum's American Museum. Beginning with the AMNH, professional scientist-curators could manage such science boundary-work by leveraging the resources of industrial elites and other sources to combine scientific research and high-brow public display. In the case of the AMNH, the scientist-curator who led the effort to establish the museum was Albert Bickmore, a student of MVZ founder Louis Agassiz at Harvard. As Bickmore described his science museum-building plan:

> [A]s science does not appear to create wealth directly, but only to use for the higher and nobler purpose of promoting original research, it seemed to me that an institution, which must depend on the interest which rich and generous men may take in it for its existence and prosperity, should be located in the immediate vicinity of their homes [in New York City]. (Rexer and Klein 1995: 24)

Gilded Age wealth bolstered this form of scientific philanthropy, envisioned by Bickmore, set apart from Barnum's entertainment empire.[21] Municipal public funding was also significant to establishing natural history museums as urban civic institutions, with the AMNH the first to receive such funding. So by the Victorian era, the leading natural history collections were to be exhibited to publics as impressive displays, akin to forms of high culture such as opera, as part of the boundary-work of increasingly professionalized scientist-curators.

High-Brow Rational Amusement:

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[21] These industrialists included J. P. Morgan, for years the most influential AMNH trustee; Andrew Carnegie, who founded his own Carnegie Museum of Natural History in Pittsburgh in 1896; and Marshall Field, who helped established the Field Columbian Museum (later renamed the Field Museum of Natural History) upon the close of Chicago's 1893 world's fair.

Glass Cases, Habitat Dioramas, and Exotics as the New **Lusus Naturae**

At the exhibitionary level, high-brow natural history museums were initially characterized by taxonomic organization and the display of specimens in rows of glass cases, as in Peale's Long Room. Linnaean taxonomy persisted, even as the Great Chain of Being was belied in the later 19th century by Darwin's theory of evolution. This awareness led to the reorganization of natural history exhibits in evolutionary series, though still in rows of glass cases. These rows of objects were intended to convey knowledge of the natural world to viewers, according to Steven Conn, who describes the phenomenon as part of Victorian museums' "object-based epistemology" (Conn 1998: 4).

This dominant mode of exhibition began to shift at the end of the 19th century and into the 20th century, as natural history museums rediscovered and reinvented habitat dioramas as a means of exhibiting specimens. This exhibitionary revival was partly the inadvertent result of the trend toward separating research collections from exhibition collections. According to Robert Kohler, in the late 1870s, natural history museums began to "separate exhibit and 'study' collections, dismounting most… Only the most attractive specimens were spruced up and kept on public display, usually those that had aesthetic appeal…or that were exotic or rare, or that illustrated a biological principle" (Kohler 2006: 108). Separating collections in this way led to changes in museums' scientific research and public exhibition practices; research could become more professionalized, while exhibits could become more flamboyant and focused exclusively on public education. The most significant manifestation of the latter trend was the habitat diorama.

Habitat dioramas and high-brow natural history museums developed in close relationship at the turn of the century and into the early 20th century. In a sense, habitat dioramas were at the crux of these museums' novel combination of scientific research and public exhibition. For while these dual objectives had seemed at odds at Peale's Museum, at the AMNH and other civic natural history museums, they gradually achieved a synergy embodied in the processes of collecting and exhibiting specimens in habitat dioramas. Still, some skeptics held on to their sense that such exhibits undermined the high-minded aspirations of natural history museums and moved too far in the direction of entertaining and pandering to publics, rather than "diffusing" scientific knowledge. As one habitat diorama critic reportedly wrote in 1874, "Spread-eagle styles of mounting, artificial rocks and flowers, etc., are entirely out of place in a collection of any scientific pretensions or designed for popular instruction. Birds look best on the whole in uniform rows…" (Lucas 1917: 87). These were the exhibitionary conventions that later science museums would move away from entirely.

On the collecting side, according to Kohler, "[I]t was the need for high-quality raw materials for dioramas that really made curators and taxidermists into field collectors" (Kohler 2006: 109). He goes on to note that museum-sponsored collecting expeditions served the dual purposes of gathering impressive specimens for habitat dioramas and more systematic scientific collecting for research. Moreover, such expeditions were attractive to the elite trustees of high-brow museums, especially if they could go along on what amounted to exotic hunting trips. "Expeditions seeking big game in exotic places were especially popular," according to Kohler (Kohler 2006: 114). At the Boston Museum of Science today, there is a kind of tribute to this heritage in Colby Gun and Trophy Room, which opened in 1965 as a replica of the den of Francis Colby, a museum benefactor. With walls lined with taxidermy and African statues, spear and shields, collected mostly between 1900 and 1945, the museum frames the room as representing “the life travels of Colonel Colby and the mindset of a generation,” including “the roots of current attitudes toward ecology and conservation.”

While the AMNH and similar museums combined scientific research and public exhibition in a novel, “high-brow” synthesis, it also highlighted unusual and bizarre specimens to draw crowds. Rather than boldly exhibiting *lusus naturae*, however, elite museums such as the AMNH emphasized the exotic. They framed exotic curiosities as respectable while distancing themselves from dime museums’ freakish curiosities and *lusus naturae*. In particular, these high-brow museums exhibited two main types of respectable curiosities: 1) dinosaurs skeletons, which paleontologists were gradually unearthing in the late 19th century; and 2) non-Western creatures and people, often in habitat dioramas. So while the AMNH’s trustees emphasized its distance from Barnumesque dime museums, “The trustees preferred to support research that had spectacular physical objects and large concrete facts such as dinosaur skeletons…for its subject matter” (as quoted in Conn 1998: 43). Meanwhile habitat dioramas recreated scenes of the African steppe or Native American life, rather than Westerners or the contemporary urban-industrial order developing beyond museum walls.

These exhibitionary conventions drew on long-standing associations between science and Western civilization, while reconfiguring them for late 19th and early 20th century urban publics. While such displays took more garish forms in dime museums, at high-brow natural history museums they bore the imprimatur of the professionalizing sciences of anthropology and zoology, as the older natural history gave way to more specialized disciplines. Natural history museum exhibits featuring non-Western peoples were also sometimes articulated with forms of scientific racism by museum professionals, including the eugenics of the AMNH’s Frederick Henry Osborn and Harvard MVZ founder Agassiz’ theories of polygeny. Yet according to the science boundary-work of the day, pseudo-science could be in the past or in lay institutional contexts, but not expert institutional contexts. Table 2 below summarizes these 19th century natural history museum types and exhibitionary conventions.

Museums: Founders & Organizational Types	***Intended Audiences***	***Exhibitionary Conventions I: Artifact Display***	***Exhibitionary Conventions II: Internal Spatial Order***	***External Spatial Order: Geographic Contexts Beyond Museum***
Peale's Museum: entrepreneurial venture by painter and amateur naturalist Peale	Relatively unprofessionalized scientific community and publics ("farmers, merchants, mechanics")	Rows of specimens in glass cases, habitat dioramas	Frontstage: Linnaean taxonomy, the Great Chain of Being; backstage: *lusus naturae*	"Wilderness" frontier, agrarian republic, limited urban development; Philadelphia initial U.S. capital
Research-oriented scientific societies (Philadelphia, Boston)	Primarily scientists (gentlemen/amateur scientists and emerging professional class of scientists)	Rows of specimens in glass cases, storage cabinets; initially for study and research, more than display per se; museums established later	Frontstage & backstage: Linnaean taxonomy; *lusus naturae* not featured	Gradual emergence of urban-industrial geographic order, expansion of the frontier, territorial surveying and incorporation; differentiated sites of scientific research and public exhibition
P.T. Barnum's American Museum (New York): profit-oriented dime museum	Broad publics, not excluding scientists – from rural visitors to urban working classes to bourgeoisie and foreign dignitaries	Eclectic mix of stuffed specimens in glass cases, living displays, and theatrical exhibitions	Loosely taxonomized; frontstage: *lusus naturae*; backstage: fabrications of show-business (rather than research or *lusus naturae*)	Growing urban-industrial order, with American Museum located in hub of U.S. urban-industrial life; expansion of frontier; European & American colonialism
American Museum of Natural History: non-profit museum with elite trustees, researcher-curators & public exhibition	Bourgeoisie publics and scientists; elite trustees; for working classes and immigrants, museum intended to be "civilizing"	Separate research & exhibition collections; specimens in glass cases; later: habitat dioramas	Frontstage: Linnaean taxonomy & exotic specimens rather than *lusus naturae*; backstage: scientific research	Consolidation of national, urban-industrial geographic order; combined emphasis on science & public exhibition in civic natural history museums

Table 2: 19th c. Natural History Museum Types, Stakeholders & Exhibitionary Conventions

In sum, over the course of the 19th century, a variety of types of science museums emerged in the U.S. These included: 1) Peale's Philadelphia Museum, often cited as the U.S.'s first science museum, an entrepreneurial venture by painter and amateur naturalist Peale that aspired to enlighten lay publics and engage scientists at a time when science was not extensively professionalized or otherwise institutionalized in the U.S.; 2) research-oriented natural history societies founded primarily by "gentlemen scientists," with associated museums that grew in importance over the course of the century, particularly the Philadelphia Academy of Sciences and the Boston Society of Natural History; 3) profit-oriented dime museums, particularly P.T. Barnum's American Museum in New York, which featured conventional natural history displays while also reveling in more freakish "curiosities" to appeal to wide publics; and 4) non-profit natural history museums supported by industrial elite trustees, particularly the American Museum of Natural History in New York.

These 19th century museums tended to frame "science" and "nature" in terms of natural history, but in different ways, as patterns of science boundary-work changed over time. In particular, there was an increasing demarcation of professionalized scientific knowledge from everyday lay knowledge, both within natural history and beyond. Professionalizing scientist-curators and industrialists established prominent non-profit science museums that differentiated themselves from earlier museums they deemed "cabinets of curiosity," such as Peale's Museum, as well as contemporary dime museums. The cultural cachet of science grew, and continued to be associated with advancing civilization and new forms of industrial "progress," even as laypeople became less credible and legitimate contributors to deliberations about natural knowledge. Moreover, the professionalization of science led to boundary-work obscuring the continuities between vulgar and respectable, "civilized" exhibitions.

This chapter has argued that 19th century U.S. natural history museums institutionalized an increasingly professionalized cultural cartography of science, which buttressed a particular (Western) conception of "civilization." 19th century U.S. science museums purported to represent not only scientific knowledge, but taxonomically ordered, civilized spaces of "rational amusement," which over the course of the century became increasingly class-based and marked as high-brow. High-brown natural history museums emphasized taxonomized displays of specimens in glass cases that have come to characterize natural history museums of this period, establishing the counter-point against which later 20th century U.S. science museums would tend to define themselves. This chapter has also argued that specimens deemed *lusus naturae* were the flipside of this boundary-work, and problematized it by representing non-Westerners, lower-class publics with "vulgar" tastes, or anomalous entities otherwise outside the "natural order" of scientific intelligibility – all of which needed to be kept at a distance.

Lastly, museums' boundary-work involving *lusus naturae* hinged on practices of collecting and displaying material culture, including the spatial dimensions of these practices. As relational spaces, early 19th century science museums shifted over the 19th century from spaces positioned to order an unknown, uncivilized wilderness, beginning with Peale's Museum, into spaces oriented toward ordering specimens for publics surrounded by a burgeoning urban-industrial order. In this context, taxonomic exhibitionary conventions became framed less around establishing a counterpoint to an unexplored Western wilderness. Instead, taxonomic exhibition helped demarcate respectable *urban* scientific culture from the disreputable, characterized by intemperate curiosity, suggesting undisciplined passions. Science boundary-work at museums became more solidly anchored in an urban-industrial social context. This urban-industrial context was generating its own abundance of artifacts, situated in landscapes of "second nature" (Cronon 1991), as discussed further in Chapter 4. Meanwhile, with the growth of Western urban-industrial life, the cultural problem of "civilizing the machine in the garden" was looming – a problem that increasingly class-based discourses of rational amusement did not address.

Chapter 4: Civilizing the Machine in the Garden, at the Edge of the Frontier: The U.S. Industrial Museum Movement and Chicago's Museum of Science & Industry

Throughout the 19th century, while natural history museums took shape through a variety of organizational forms and exhibitionary conventions, on the whole, a "science museum" meant a natural history museum. It meant an institution of collection and/or display based on the artifacts, practices and narratives of natural history, rather than some other interpretation of "science." In other words, natural history's "nature" was mutually constitutive of the "science" practiced and displayed within 19th century science museums – whatever the variations in museums' founders, intended audiences, conventions of artifact display, or patterns of internal spatial ordering. Meanwhile, beyond museum walls, this natural history framework of nature and science articulated with U.S. exploration, surveying, the expansion of the Western frontier, and territorial incorporation. This framework of nature and science was intertwined with transforming lands that became the U.S. into a *national landscape*, in other words – bounded, mapped and ready for use by its new inhabitants.[22] This ordering of space for "nature," science and nation – both within museums and beyond – was accomplished both via artifacts and via narratives of civilization, Manifest Destiny, progress, Enlightenment, rationality, modernity, and evolution. The narratives of the geographic explorer and the scientific inquirer were not far apart.

Yet, throughout the 19th century, another science museum genealogy was also developing – a genealogy of mechanical and technical display, that was, in turn, articulated with the burgeoning urban-industrial landscaping project that came to overlay the natural history landscaping project. This was especially true as world's fairs transformed mechanical and technical exhibition, and catalyzed the founding of European industrial museums. This genealogy would emerge fully fledged as part of the U.S. science museum field only in the 20th century, in the form of industrial museums, but it appeared increasingly throughout the 19th century. It framed "science" in terms of the "applied science" of industry and engineering, rather than in terms of natural history, and "nature" in terms of natural resources for industry.

In this chapter I first discuss the 19th century genealogy of 20th century U.S. industrial museums, and then examine the industrial museums movement of the 1920s and 1930s, particularly the founding of Chicago's Museum of Science & Industry and the reinvention of the Franklin Institute. I discuss the ways in which industrial science museums drew on and departed from natural history museum conventions of exhibition, including by reconfiguring the terms of "rational amusement." One element of this reconfiguration was the disappearance of explicit discussions of *lusus naturae* at industrial science museums. Arguably, concerns about *lusus naturae* were replaced by the utopian, sci-fi sensibility of world's fairs – which often recast entities beyond the contemporary "natural order" of things not as monstrous, but as progressive and desirable. I also discuss the relations between the larger national landscaping projects in which natural history and industrial museums were intertwined. Finally, at the MSI, I discuss the shift toward a more consumer-culture oriented model of museum, especially after World War II.

19th Century Underpinnings: A Genealogy of 20th Century Industrial Science Museums

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[22] Table 2 in Chapter 3 summarizes 19th century geographic patterns beyond museums – or the "External Spatial Orders" that accompanied museums' "Internal Spatial Orders," as part of the broader context of their exhibitionary conventions.

Below I discuss the 19th century genealogy of 20th century U.S. industrial museums, of which three had been established by the late 1930s: Chicago's Museum of Science and Industry, opened in 1933 in conjunction with Chicago's "Century of Progress" world's fair, on grounds leftover partly from the 1893 Columbian Exposition; The Franklin Institute in Philadelphia, founded in 1824 as a mechanics' institute and reopened as a science and industry museum in 1934; and New York's Museum of Science & Industry (initially known as the "Museum for the Peaceful Arts"), opened in 1936 after years of correspondence with U.S. and European industrial museums, many of which were catalyzed by world's fairs. Laurence Vail Coleman, president of the American Association of Museums (AAM), highlighted these three institutions as comprising a new classification of museum in his 1939 study for the AAM, *The Museum in America*. As Coleman wrote, "Three institutions make up a much discussed group of industry, or applied science, museums" (Vol. 1: 93). "[T]he three new industry museums…form a class by themselves…" (Vol. 1: 94). The associations among these industrial museums, world's fairs and mechanics' institutes was nothing new, however, as illuminated by 19th century genealogies of mechanical and technical exhibition.

In the 19th century, mechanics' institutes and especially world's fairs became increasingly pivotal to framing "science" for publics, by institutionalizing conventions for the collection and exhibition of the mechanical arts – later referred to as technology, applied science, or industry. In the context of science museums, these terms became interchangeable by the late 19th century.[23] While 17th and 18th century cabinets of curiosity often included mechanical models, full-fledged museums along these lines did not take shape until the 19th century, due to the influence of industrial fairs, mechanics' institutes, and – most of all – world's fairs. As Eugene Ferguson summarizes this genealogy, "[W]ith few exceptions today's technical museums owe their existence to the international exhibitions of the nineteenth century" (Ferguson 1965: 30). 19th century mechanics' institutes and world's fairs were pivotal to catalyzing the formation of industrial museums, first in Europe and later in the U.S. – though European aristocrats collected mechanical devices in cabinets of curiosity centuries earlier. These institutions established conventions for the collection and display of industrial material culture alongside the natural history and ethnographic material culture that largely defined the U.S. science museum field throughout the 19th century. They both drew on and departed from natural history museum conventions of exhibition, including by reconfiguring the terms of "rational amusement," thereby establishing distinct patterns of boundary-work in their exhibitions and institutional framings. World's fairs – containing as they did both natural history displays and collections of industrial manufactures – were also intertwined with both the natural history landscaping project of surveying "first nature" and the urban-industrial landscaping project of constituting "second nature" that came to overlay it.

[23] In this dissertation I use the terms "industrial science museum" or "industrial museum" instead of technical museum, because when proponents of such museums mobilized in the U.S. in the 1920s and 1930s, they referred to them as industrial museums or museums of science and industry. Also, U.S. typologist of museums, George Brown Goode of the Smithsonian, discussed industrial museums and technical museums as interchangeable in his 1896 article, "On the Classification of Museums."

Industrial Exhibitions & Museums: Founders & Organizational Types	***Intended Audiences***	***Exhibitionary Conventions I: Artifact Display***	***Exhibitionary Conventions II: Internal Spatial Order***	***External Spatial Order: Geographic Contexts Beyond Museum***
19^{th} century mechanics' institutes (including the Franklin Institute in Philadelphia)	Mechanics and technically-oriented manual workers	Artifacts to be used and learned from, as resource for further invention & innovation	Patent & invention collections; vocationally oriented machines	"Wilderness" frontier, agrarian republic, limited urban development; Philadelphia initial U.S. capital
19^{th} & 20^{th} century world's fairs & industrial exhibitions	Broad publics, including growing middle classes, in increasingly industrialized and consumption-oriented Western societies	Rows of classified artifacts, including in glass cases, a la natural history; multifaceted educational displays; museums sometimes established post-fair	Linnaean taxonomy and attempts at Enlightenment taxonomy for industrial material culture; *lusus naturae* particularly in anthropological midway exhibitions	Growing urban-industrial order; territorial surveying, incorporation, and "closure of frontier"; European & U.S. colonialism; science increasingly specialized, professionalized, industrialized
Late 19^{th} & early 20^{th} century industrial museums: first in Europe, then the U.S.	Intended for broad publics as part of industrial education, in roles of consumers as well as producers; often grew out of world's fair collections	Industrial material culture taxonomized, as at world's fairs; also: diorama-type displays and working/cut-away machine models	Organized via branches of science and industry, with implication that industry is "applied science"; *lusus naturae* per se no longer relevant	Consolidation of national, urban-industrial geographic order; physics, chemistry and industrial "applied sciences" attain higher status than natural history
Mid to late 20^{th} century industrial museums: U.S.	Intended for broad publics, but especially children and families; adult audiences must look elsewhere for science/technical education	Shift away from taxonomies and artifact collections, and toward recreated landscapes & immersive environments	Some "backstage" research at Franklin up until 1980s, but in general, emphasis on "hands-on" exhibits	Consolidation of overseas colonies and spheres of influence; initiation of outer space race and foundations of cyberspace

Table 1: 19^{th}-20^{th} c. Industrial Exhibition Types, Stakeholders & Exhibitionary Conventions

Mechanics' Institutes as 19th Century Sites of "Hands-On" Science: Early Technical Collections & the Franklin Institute

More than a century before the formation of technical or industrial museums, the earliest U.S. technical collections were associated either with learned societies devoted to the mechanical or "useful arts," or with patent offices. For example, Benjamin Franklin's American Society for Promoting and Propagating Useful Knowledge formed one such early technical collection in 1766. Two years later, the learned American Philosophical Society took over and continued this collection. These early technical collections often consisted of accumulations of mechanical models submitted for inventing competitions or patent applications. Artifacts were intended as practical aids to learning and further invention. Such pedagogic approaches shared with publicly oriented natural history museums an emphasis on "object lessons." However, while natural history museums emphasized the visual aspects of artifacts as the key to their lessons, mechanics' institutes emphasized the tactile, manual aspect of object lessons. They were not training in connoisseurship or natural history observation, but forms of manual education – an early version of "hands-on" science education in the U.S., though in the context of vocationally oriented industrial education, unlike most "hands-on science" at late 20th century science museums.

The use of technical collections as learning aids was especially prominent at a new institution of technical education that arose in the early 19th century, first in Britain and then in the U.S.: the mechanics' institute. While the apprentice system had previously taken care of vocational technical education, as industrial factories replaced craft-based workshops and the apprenticeship system waned, mechanics' institutes were among the entities that strove to fill the gap in vocational technical education by providing basic technical education for workers. Mechanics' institutes were also deemed important as mechanical skills in industry became more specialized and based on new applications of science, compared with craft knowledge. The increasing demarcation of professionalized scientific knowledge from everyday lay knowledge took place in industry as well as natural history over the course of the 19th century. In industry, however, this demarcation of scientific expertise often had more overt class dimensions and implications, including the deskilling of certain jobs as new professions emerged. Indeed, various scholars have argued that mechanics' institutes fostered scientific understanding and the technical skills of workers in a mold oriented toward social control. As Shapin and Barnes write, "[T]he movement's leaders…belie[ved] that a regimen of scientific education for certain members of the working class would render them, and their class as a whole, more docile, less troublesome, and more accepting of the emerging structure of industrial society" (Shapin and Barnes 1977: 32). At the same time, Shapin and Barnes find that workers exposed to mechanics' institutes were not effectively inculcated with the views and attitudes that elites intended. Yet mechanics' institutes left a legacy of technically oriented object lessons and interpretive frameworks that later industrial museums would draw on.

Foremost among the mechanics' institutes in the U.S. was the Franklin Institute in Philadelphia – or "The Franklin Institute of the State of Pennsylvania, for the Promotion of the Mechanic Arts" – founded in 1824 and named for Benjamin Franklin. While in Britain mechanics' institutes were formed by industrial businessmen and managers, in the U.S. they were formed by mechanics themselves (Ferguson 1965: 33-34). Thus compared with institutes in Britain, the Franklin Institute and other U.S. mechanics' institutes arguably placed less emphasis on social control and greater emphasis on expanding opportunities for workers through technical education, including education based on mechanical collections and exhibitions. The Franklin

Institute organized its first exhibition, the "American Manufactures Exhibition," the same year it was founded, and at least twenty-five similar exhibitions during the next thirty-four years (Ferguson 1965: 34). These exhibitions featured prizes for inventions and led to a permanent collection of models in the institute's library. Years later, some of these early artifacts are still on display at the Franklin Institute, which reopened in its present incarnation as a science museum in 1934.

As at contemporary natural history institutions, there was also a national dimension to the Franklin Institute's activities. The goal of expanding opportunities for workers – while perhaps shaping their aspirations – was intertwined with aspirations for national development, to which specialized scientific knowledge was deemed vital in order to make commercial use of the U.S.'s abundant natural resources and sustain technical innovation. As Sinclair writes in his book on the Franklin Institute:

> At the center of all [American mechanics' institutes'] hopes for the country's material progress and the ultimate proof of the democratic experiment was a new man, the 'scientific' or 'intelligent mechanic'…Of all those qualities which would distinguish the intelligent mechanic from the workman of the past, the most important was his knowledge of science. More particularly, it was his understanding of the scientific principles which lay behind his art. A thorough knowledge of those basic and unchanging natural laws, when united with skillful practice, would enable him to perceive new combinations of materials and new uses for them. He would…be able to escape that cycle which had limited craftsmen for centuries, that need to rediscover the same truths every generation. Technical knowledge would become cumulative, and that meant progress. (Sinclair 1974: 15)

Thus the exhibitions at the Franklin and other mechanics' institutes were intended to provide a certain kind of technical education for workers, in the context of increasingly professionalized scientific disciplines and "applied science" occupations, such as engineering. They were also meant to stimulate further invention and technical innovation, thereby fostering national development in material cultural terms – contributing to an urban-industrial landscaping project. Such material "progress" would, in turn, reflect positively on U.S. political and social structures. It would provide what Chandra Mukerji (2010) has referred to as a logistical basis of legitimacy. Put another way, an early kind of modernization theory was implicit in mechanics' institutes' framing of science, technical innovation and national development. This linear, nationally- and technically-oriented model of "progress" would also be prominent in an even more influential 19th century institution of technical collection and exhibition: the world's fair.

From Hands-On Vocational Education to Educational Spectacles: World's Fairs & the Emergence of Industrial Museums

In 1851 in London, an even more significant 19th century institution for the collection and display of the "mechanical arts" made its debut: the first world fair. After the 1851 watershed, the industrial exhibitions organized by mechanics' institutes became like lesser world's fairs. World's fairs showcased the industrial achievements of European nation-states, contrasting the material cultural production of these nation-states as well as their less industrialized colonies. As Robert Rydell writes, "Long before the Internet and the World Wide Web, another network – a veritable web – of world's fairs ringed the globe, giving form and substance to the modern world…Fairs have introduced generations of Americans to pathbreaking scientific and technological innovations like telephones, X-rays, infant incubators, television, moving walkways, asphalt, and plastics. The architecture and park-like settings of world's fairs, along with their sometimes visionary schemes for public and private transportation, have influenced the ways our cities and small towns look and the way we behave in them" (Rydell et al. 2000: 1-2). Rather than the vocationally oriented, hands-on technical education of mechanics' institutes, world's fairs provided visitors with educational spectacles, featuring new scientific breakthroughs and technologies. As the writer Henry Mayhew assessed the first world's fair, the 1851 Crystal Palace Exhibition: "If we really desire the improvement of our social state (and surely we are far from perfection yet), we must address ourselves to the elevation of the people; and it is because the Great Exhibition is fitted to become a special instrument to this end, that it forms one of the most remarkable and hopeful characteristics of our time" (as quoted in Gold and Gold 2005: 65). World's fairs were framed as grand vehicles of popular education and uplift, particularly suited for the dawning era of urban-industrial capitalism and consumption.

London's 1851 Crystal Palace Exhibition, or "The Great Exhibition of the Works of Industry of All Nations," not only inaugurated a world's fair movement that would spawn numerous other international expositions in the coming decades. The exhibition also inaugurated the catalytic relationship between world's fairs and industrial science museums, both in terms of material artifacts and cultural taxonomies and narratives. As Rydell puts it, there has been "…a hand-in-glove relationship that existed historically between world fairs and museums" (Rydell in Carbonell: 135). World fairs have been a source of museum collections, buildings, and exhibitionary conventions – while also drawing on taxonomies akin to those at natural history museums to classify a wider world of things. Indeed, world's fairs were the 19th century's encyclopedic institutions of collection and display, bringing together objects and peoples from far and wide.

The 1851 fair left behind collections that went on to form the Victoria and Albert Museum of Art and Design (initially The Museum of Manufactures) as well as the Science Museum of London. The latter became one of Europe's foremost industrial science museums, and would later influence U.S. industrial museum entrepreneurs. Another touchstone museum for U.S. industrial museum builders, Vienna's Technische Museum fur Industrie and Gewerbe, was catalyzed by the Vienna International Exhibition of 1873. Meanwhile the model for Chicago's Museum of Science & Industry, the Deutsches Museums in Munich, reportedly grew out of founder Oskar von Miller's experiences visiting the 1881 International Electrical Exposition in Paris (Ferguson 1965: 30). The Deutsches Museum was also a key reference point for founders of New York's Museum of Science & Industry, initially known as the Museum of the Peaceful Arts.[24] Meanwhile the overarching cultural narratives of science at world's fairs – including framing industry as "applied science" and both industry and science as synonymous with "progress" – shaped the meanings of museum collections formed in their wake.

While 19th century world's fairs did not directly catalyze the formation of industrial museums in the U.S. as they did in Europe, they did lead to an influx of industrial material culture into U.S. museums, accompanied by various attempts to classify these new museum objects vis-à-vis the existing science museum field. Initially, industrial artifacts from world's

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[24] In the will of engineer Henry Towne, who bequeathed his fortune to establish the museum, the peaceful arts are described as "agriculture, animal industry, forestry and wood working, mining and metallurgy, transportation and communication, engineering and architecture, industrial chemistry, electrical mechanisms, aeronautics, textiles, building trades, all of these including products, processes and implements."

fairs tended to be placed in natural history museums. Later, however, industrial artifacts were often reclassified as belonging in distinct, industrial (or technical) museums. Indeed, these artifacts sometimes contributed to initiatives to found such museums, to exhibit objects that no longer seemed to fit among natural history and ethnographic collections. As Pinch describes such materially contingent agency, "Boundary shifters work with liminal entities to cross boundaries to produce transformations in institutions" (Pinch 2008: 479).

For example, the first U.S. world's fair – the 1876 Centennial Exhibition in Philadelphia – led to a burgeoning collection of artifacts at the Smithsonian,[25] including industrial machinery. These industrial artifacts were initially placed in the Arts and Industries Department within the Division of Anthropology (Molella 1991), overseen by a curator of mechanical technology whose collections encompassed locomotives as well as Eskimo dogsleds. However, as greater disciplinary professionalization and specialization took hold among Smithsonian curators in the early 20th century, industrial artifacts came to be seen as increasingly distinct from the rest of the anthropology collection. In the 1920s, these technical artifacts formed the material cultural basis of some Smithsonian curators' initiative to found a National Museum of Engineering and Industry – an industrial science museum – distinct from anthropology and natural history. (This museum did not, however, come to fruition along with the other proposed industrial museums of the 1920s and 1930s.) Similarly, in Chicago, the Field Columbian Museum that formed after the 1893 World's Columbian Exposition initially contained a Department of Industrial Arts, alongside departments of anthropology, geology, botany, zoology, and ornithology. The early Field Museum thus brought together both industrial artifacts and natural history collections. When Chicago's Museum of Science & Industry formed in the 1930s, it acquired the ship collection and other industrial artifacts from the Field, thereby separating industrial material culture from natural history and ethnographic collections – sequestering them in distinct types of science museums. These developments indicate museum professionals' gradual reclassification of industrial artifacts from natural history museums to distinct, industrial science museums. In the process, they tended to reinforce Western cultural categories of the "primitive" and "civilized," which were prominent at world's fairs and in strands of early anthropology.[26]

However, the majority of industrial artifacts from the 1893 fair went not to the Field Museum, but to another type of museum formed after the fair: Philadelphia's Commercial Museum. According to George Brown Goode of the Smithsonian, in his 1896 article on museum classifications:

> The Commercial Museum has to do with salable crude materials and manufactured articles; with markets, means of commercial distribution, prices and the demand and supply of trade… It may properly be connected with the Technological Museum, but for the fact that its purposes are more likely to be

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[25] Smithsonian curator-naturalists Spencer Baird and George Brown Goode organized the U.S. exhibition at the fair, and later leveraged the influx of materials to secure funds for a new museum building. Goode would go on to actively bridge the exhibitionary worlds of museums and world fairs, including by theorizing about classifications of material culture and exhibitionary practices.

[26] To many early anthropologists, industrial artifacts distinguished modern, civilized society from so-called primitive, savage societies. As Berkeley anthropologist A. I. Kroeber wrote in 1922, "In many cases it is the very lack of development of other arts that has led to the special development of basket making [among the California tribes]…. There is little doubt that civilized people, if they took up the matter seriously, would outdistance the savage at his own game, in basket making as in other undertakings."

> akin to those of the exposition or fair, involving a frequent renewal of exhibits in connection with commercial changes…. (Goode 1896)

Thus the commercial museum and the technological (or industrial) museum were two overlapping and in some ways competing classifications for industrial artifacts in the late 19th and early 20th century U.S. museum field. At issue was whether industrial artifacts were object lessons in commerce, or in science – specifically, applied science. Ultimately, the commercial museum model was unsuccessful. Philadelphia's Commercial Museum opened in 1899 and continued through 1926, before folding. While there have since been numerous successful company museums devoted to particular brands, there has been no generic, explicitly "commercial museum" following the model of Philadelphia's Commercial Museum. Meanwhile the 1920s were the same years that the industrial museum movement got successfully underway in the U.S., to establish museums for industrial artifacts such as those in the Philadelphia Commercial Museum. In this sense, the latter arguably represents a failed museum classification for the collection and display of industrial artifacts, compared with the industrial museum movement's foregrounding of "science."

Thus the emergence of U.S. industrial museums reflects not only a demarcation of industrial from natural history artifacts, but the relative ascension of an applied science rhetoric to frame industrial artifacts at museums, however mixed with commercial subtexts. This rhetoric echoed the discursive frames of world's fairs themselves, and an "applied science" classification became a crucial element of the institutionalization of industrial artifacts in the science museum field. This rhetoric dovetailed with museums' general discourse of framing items in "collections" as distinct from commodities, market exchange, and market metrics of valuation (Belk 1995). It helped to establish industrial artifacts as collectible and valuable beyond the commercial, capitalist contexts in which they were manufactured, distributed and sold. Taxonomic classificatory schemas were instrumental to framing exhibits in such a light, as "scientific" and instructional. Yet industrial science museums were still much closer to consumer market logics than natural history museums had been – in their relative (if not complete) neglect of research, their artifacts and exhibitionary conventions, and related attempts to be popular.

This frame of "applied science" impinged not only on industrial artifacts but also on the status of publics' knowledge, including their knowledge of machines as workers and craftsmen (Sennett 2008). It dovetailed with conceiving of world's fairs and museums as sites of "diffusing" scientific expertise to laypeople, in an urban-industrial world of professionalizing scientists, in natural history as well as industry. Indeed, both world's fairs and museums were increasingly predicated on the demarcation of professionalized scientific knowledge from everyday lay knowledge. As Goode articulated this binary view of knowledge, "All intellectual work may be divided into two classes, the one tending toward the increase of knowledge, the other toward its diffusion; the one toward investigation and discovery, the other toward the education of the people and the application of known facts to promoting their material welfare" (Kohlstedt 1991: 308). This diffusion approach to science popularization depended on the growing professionalization of "applied scientists," as opposed to mechanics or craftsmen.

In sum, 19th century mechanics' institutes and especially world's fairs catalyzed the formation of leading industrial science museums first in Europe and later in the U.S., including through the influx of industrial artifacts to U.S. museums and varied attempts to classify these objects – attempts that proved more or less viable over time. The synergistic relationship between world fairs and industrial museums – among other museum types – stemmed from shared material artifacts, as well as common cultural taxonomies and narratives, as discussed further below. Together, the natural history and mechanical arts traditions, and the museum sites in which they were institutionalized, grappled with the overarching cultural problem of "civilizing the machine in the garden" of the U.S., as it became an urban-industrial nation-state with more industrial engineers and applied scientists than natural philosophers, Deist natural historians or craftsman mechanics. These traditions and institutions would go on to constitute the 20th century U.S. science museum field, in which this cultural problem is naturalized such that the deeper conflicts among participants in the science museum field are usually not addressed.

The U.S. Industrial Museum Movement: Entrepreneurs & Cultural Objectives

What motivated entrepreneurs involved with the U.S. industrial museum movement, and what did they accomplish? In brief, it was a movement by a handful of U.S. industrial, engineering and corporate elites in the 1920s and 1930s that drew on 19th century precedents to establish museums to achieve the following cultural objectives: 1) to collect and display manufactures and industrial artifacts, including preserving the national patrimony in industrial material culture, as did European museums; 2) to portray industry as "applied science" to U.S. publics, and to frame science in industrial terms, in a purportedly hallowed cultural zone apart from the market (often articulated with cultural narratives of the "progress" of Western civilization, via science and industry); and 3) to establish science museums with more populist modes of exhibition, in contrast to the "hands-off" displays of 19th century natural history museums, in the process associating industrial artifacts with "animation" and vitality, appropriate to "museums for a new age." These goals tended to be intertwined with civic boosterism, as museum entrepreneurs framed industrial science museums as a new, vital cultural institution that any leading city should have. Thus the U.S. industrial museum movement sought to collect and display manufactured material cultural artifacts in particular cultural taxonomies and narratives, which were nonetheless infused with the naturalizing rhetorics of science. The movement then framed these collections as a basis for civic competition and evidence of cities' modernized, "civilized" status.

The most prominent players in the U.S. movement were based in Chicago and New York, including: Julius Rosenwald, former president and then chairman of the board of Sears, Roebuck, & Co., and associates in the Chicago Commercial Club, who went on to found Chicago's Museum of Science & Industry; and the estate and associates of Henry Towne, an engineer and head of the Yale & Towne Mfg. Co., who went on to found the New York Museum of Science and Industry (initially the Museum for the Peaceful Arts) in New York. Also important were executives at Philadelphia's Franklin Institute, the aforementioned Smithsonian curators, and Henry Ford, who strove to establish an industrial museum during this period. Ford's effort came to focus on U.S. industrial history, however, rather than foregrounding science, so it is not considered further here. What the industrial museums in this chapter shared was an emphasis on industry *as applied science* – or, put another way, on "nature" in terms of natural resources, and science as the "applied science" of industry and engineering, rather than in terms of natural history. As the epigram carved into the marble ceiling of the MSI's rotunda puts it: "Science Discerns the Laws of Nature. Industry Applies Them to the Needs of Man."

U.S. industrial museum entrepreneurs modeled their efforts after existing industrial museums in Europe, seeking to "catch up" with Europe in this cultural sector – particularly after the museum-building efforts that followed 19th century world's fairs, as discussed above. European industrial museums presented both a spur to and models for U.S. museum-building efforts, and included: the Conservatoire des Arts et Metiers in Paris; the Science Museum of

London; the Deutsches Museum in Munich; and the Technical Museum of Vienna, as well as several smaller museums (Richards 1925). The Deutsches Museum was the most influential of this group, and exchange between the Deutsches Museum and founders of Chicago's MSI was particularly intensive. The MSI's iconic Coal Mine exhibit, discussed below, was even modeled after a similar exhibit in the Deutsches Museum.

As a programmatic statement, an important touchstone for the U.S. industrial museums movement was the book *The Industrial Museum* (1925), by AAM president Charles Richards, based on his 1923-1924 studies of European industrial museums.[27] In this book, Richards highlights the leading European industrial museums mentioned above, as well as the apparent irony that the U.S. lacks a similar museum. As he writes:

> We are today one of the foremost industrial countries of the world. Can we afford to omit from our educational program the story of what has made us? We have developed a high type of industrial organization and as a people we are the first to utilize the fruits of new inventions. Shall we leave other nations to grow wise through the study of our achievements and ourselves neglect their meaning and their inspiration? (Richards 1925: 48)

Industrial museum entrepreneurs repeatedly noted this irony. Many of those involved in establishing U.S. industrial museums, from curators to industrialist funders, embarked on trips to Europe to study and report back on the continent's industrial museums, to highlight this purported hole in the U.S. cultural landscape and assert the need to "catch up."[28] Meanwhile Oskar von Miller, the founder of Munich's Deutsches Museum, which served as the primary model for Chicago's MSI and the new Franklin Institute museum, in 1929 published his own white paper on "Technical Museums as Centers of Popular Education" (published in English in 1931).

Besides serving as a symbol of cultural achievement, one of the perceived practical consequences of the U.S.'s lack of a full-fledged industrial museum was that its industrial artifacts – its technological patrimony – could be lost to European museums. Industrial museum entrepreneurs sometimes emphasized this point in their efforts to win support for their efforts. For example, the opening page of Charles Gwynne's 1927 pamphlet, "Museums of the New Age," features a photograph of a record player with the caption:

> The Edison Phonograph at London. The American inventor of this famous, original, first practical instrument of its kind, that is now in the permanent possession of The Science Museum at South Kensington, has stated that he cares more for it than for any other of his numerous creations. He gave it to London because in all the United States there was not a similar museum where such a relic could be a worth-while force in science and industry. (Gwynne 1927)

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[27] Waldemar Kaempffert mentions Richards' book as the main guide available to the Chicago Commercial Club's Museum Committee as it set about establishing Chicago's MSI (Kaempffert 1933: 8), before Julius Rosenwald, Kaempffert and others provided the Committee with their own reports on European industrial museums.

[28] These reports included the 1927 pamphlet, "Museums of the New Age: A Study of World Progress in Industrial Education," by Charles T. Gwynne, a leader in efforts to establish the Museum of the Peaceful Arts; an 84-page "Report on Studies of Palace of Discovery, Paris International Exposition, Museums of Science and Industry, and Other Exhibitions in Europe," by Robert P. Shaw for the New York Museum of Science and Industry, dated Nov. 22, 1937; and another 55-page report by Waldemar Kaempffert, first director of Chicago's Museum of Science and Industry, focusing specifically on the Deutsches Museum, the principal model for the MSI, dated Feb. 1, 1929.

Thus a desire to collect and display industrial artifacts in order to preserve the national patrimony in industrial material culture was one crucial cultural objective of U.S. industrial museum entrepreneurs. In this sense, the industrial museums movement was simultaneously transnational in scope and Western, nationalistic and capitalist in character.

Industrial museum entrepreneurs also wanted to discourage public backlashes against industry, supposedly due to people's lack of understanding of science and industry. As one of the leaders in efforts to establish the Museum of the Peaceful Arts, F. B. Jewett, puts it in his 1936 essay, "The Newest of the Museum Family":

> [N]o industry, large or small, can long escape being cited before the bar of public opinion as to some phase of its operations. When that time comes, if we feel we have a just case, we will wish for a public jury that has some understanding of our problems and not one moved wholly by emotions…Just now we are obviously in the midst of a revolution many of the roots of which are in the results of applied science…The waves of our present turmoil will not subside into the new order for years to come…[A] wider understanding of what science can and cannot do will accelerate the return to more quiet and prosperous conditions. In this evolution museums of science and industry can play a powerful role. (Jewett 1936)

Thus industrial museum entrepreneurs framed the upheavals of the industrial revolution and public responses to them not in terms of social relations and power, but rather in terms of the possibilities and limitations of "applied science." Industrial museum entrepreneurs strove to convey to U.S. publics the idea that industry is "applied science," and to frame science in industrial terms in the relatively hallowed cultural zones of museums set apart from the market. Again, this frame is distilled in the MSI's epigram, which suggests that science and industry are inherently linked, together serving human betterment.

In the course of portraying industry as "applied science" and framing science in industrial terms, industrial museums also often articulated artifacts and displays with cultural narratives of the "progress" of Western civilization, via science and industry. While such narratives were most prominent at the world's fairs, including those that gave rise to industrial museums, such as the Century of Progress world's fair that opened alongside Chicago's MSI in 1933, they were also present in more subdued and subtle forms in industrial museums themselves. For example, MSI's first exhibit guide was entitled, "*From Caveman to Engineer: The Museum of Science and Industry Founded by Julius Rosenwald, An Institution to Reveal the Technical Ascent of Man*" (Kaempffert 1933). This exhibit guide, in turn, cribbed phrases from Richards' book *The Industrial Museum*, which began: "In the Far East, particularly in India, the processes of production that underlie the daily life are revealed to every passerby…With us in the West all this is different. The processes of production that underlie the civilization of today are hidden behind factory walls where only the specialized factory worker enters" (Richards 1925: 1). Richards suggests that Western civilization is more complex and difficult to understand, based on industrial processes located in factories. Indeed, Kaempffert, the exhibit guide's author and MSI's first director, subscribed to the views of an early "sociology of invention" articulated in the 1920s and 1930s by William Ogburn and others, which argued that invention was determined by "culture," with Western culture being the most inventive and advanced (McGee 1995: 773-4). Such thinking is arguably part of the longer intellectual history, discussed first and foremost by Michael Adas, of Westerners associating technological material culture with "progress" and Western superiority, overlapping with the intensified innovations of the Industrial Revolution in the 18th and 19th centuries (Adas 1989: 22; 28).

Finally, U.S. industrial museum entrepreneurs sought to establish science museums with more populist modes of exhibition, in contrast to the "hands-off" displays of 19th century natural history museums – drawing on and departing from natural history museum conventions of exhibition in the process, including by associating industrial artifacts with "animation" and vitality. As Lawrence Vail Coleman wrote in his 1939 study, industrial museums were distinguished not only by the novel exhibitionary content of industrial artifacts and applied science exhibits, but also novel modes of presentation. As he puts it:

> Distinctive methods are used by industry museums in their exhibits…. Their exhibits can work. Their visitors can press buttons and pull levers. And from such things it is but a step to motion pictures and phonographic talks. Finally, there are performances, such as a trip through the Chicago museum's coal mine where the guides have to carry spirits of ammonia for those who fall victim to illusions of depth and dangerous passage. These methods cannot be much employed by museums of other kinds. It is not a question of ingenuity but of circumstances. Industry museums represent a field of action, and they can interpret it through action. (Coleman 1939, Vol. 1: 98)

Contemporary commentators repeatedly emphasized action, movement and animation as uniquely characterizing industrial science museums – inviting visitors to not only look, but also touch hands-on exhibits. Such exhibitionary approaches were contrasted with both "hands-off" specimens in natural history museums and the textbook learning of schools. As Dr. F. C. Brown, a director of the Museum of the Peaceful Arts, explained this motivation:

> The great purpose of our industrial museum is to interpret our mechanistic age for all classes and professions. Words, however well expressed, can only give a vivid understanding when firsthand experience furnishes a background…. Language at its best is so inadequate to convey the ideas where there is lacking the background, even if we had unlimited time to read. Thus the industrial museum comes in to fill the gap, to portray the growth of the industries and the underlying sciences for the common understanding of all people. (Brown 1929: 340-341)

Julius Rosenwald reportedly first started thinking about founding an industrial museum in Chicago after witnessing his young son's delight at the hands-on, push-button operated exhibits at the Deutsches Museum during a family visit, an experience that contrasted with their staid art gallery visits. Later commentators would describe these novel exhibitionary approaches as "interactive" and "hands-on," enabling novel practices of manipulation and observation, part of science pedagogic discourses that emphasized public engagement with and understanding of science.

Industrial museum builders' vision of a more interactive museum was in a sense populist, then, in the tradition of U.S. museums reformer John Cotton Dana, who advocated moving away from European models of the museum-as-temple or museum-as-palace, with their sacralization of objects, to emphasize utility and interactivity between publics and museum exhibits (Dana 1999; DiMaggio 1991). Yet this populism, while challenging the dominant museum model articulated by Benjamin Ives Gilman (1918) of the Boston Museum of Fine Arts, hardly embodied a deeply democratic vision – one concerned with more egalitarian agency in all areas of public life. Rather, it was consonant with the populism of consumer capitalism, or “consumer populism,” as historian William Leach described the museum methods of Dana and other museum leaders (Leach 1993: 168), who saw their museums as resources for industrial designers and business people and fashioned them after department stores. The interactivity of industrial science museums likewise fit into this mold.

In sum, the cultural objectives frequently expressed by industrial museum entrepreneurs in programmatic statements and exhibition guides could be described as industrial capitalist, nationalist and Western in their orientation, as well as populist in their rhetoric. Often they were also intertwined with municipal civic pride and the desire to establish a new cultural institution that would heighten the status of the city where it was situated – to evince a city’s status as modern and civilized. This was particularly the case in Chicago, the so-called “second city” of the U.S. compared with New York, as discussed further in the next section.

Civic Boosterism & the Changing Built & Media Environments of Industrial Cities

Turning to examine specific industrial museums, of the three new “industrial science museums” Lawrence Vail Coleman mentioned in his 1939 report, only two continue today: Chicago’s MSI and the Franklin Institute (while New York’s Museum of Science & Industry quietly closed in 1952). Both drew inspiration from and were modeled primarily after the same European museum – Munich’s Deutsches Museum, mentioned above. Below I briefly discuss the Franklin Institute’s reinvention as an industrial museum, re-opening as such in 1934. Then I develop a more in-depth discussion of Chicago’s MSI. This case study enables analysis of how the industrial museum movement’s cultural objectives were instantiated in a particular built environment and an array of exhibitionary practices, performing new types of science boundary-work compared with natural history museums. Also examined are the ways that industrial science museums’ exhibitionary practices changed over time, especially as they came to compete with the new mass media ecology of film, radio and television.

The Reinvention of the Franklin Institute:
From Vocational Technical Education to Populist Spectacles & “Hands-On” Science

As discussed above, the Franklin Institute was founded in the early 19^{th} century as a quite different sort of institution from its later 1930s incarnation as an industrial science museum. While also quite distinct in its institutional objectives, contents and the use of its collections from 19^{th} century natural history museums, it shared their emphasis on combining public education with research. This commitment to research would set it apart from 20^{th} century science museums emphasizing industry and technology. Hence, it is interesting to examine how and why this commitment waned – or was transformed – as the Franklin Institute was reinvented in the 20^{th} century. Doing so sheds light both on the relations between natural history museums and later industrial science museums, as well as the forces shaping contemporary science museums as sites of scientific practice and public engagement, including the parameters of such practice and engagement. I examine two main historical junctures: the opening of the Franklin Institute’s new industrial museum in 1934, and the closure of all its research facilities by 1983. Below I look at the first of these junctures – the opening of the Franklin Institute’s new industrial science museum. In Chapter 5, I examine the Franklin Institute’s late 20^{th} century transformation, with its participation in that period’s “science center movement” and the cessation of its research activities.

One manifestation of the Franklin Institute’s early commitment to research, in addition to vocational technical education, was its journal *The Journal of the Franklin Institute*, which began publication in 1826. Its purpose was to publish U.S. patent information – given the early overlap between technical and patent collections – as well as to document scientific studies and technological discoveries throughout the U.S. (While still published today, it is now devoted mainly to applied mathematics.) Though the journal remained a vital contributor to public scientific and technological discourse throughout much of the 19th century, by the turn of the 20th century, both the journal and the Franklin Institute itself had waned in relevance. As museum historian Steven Conn puts it, in some respects the Franklin Institute had become a victim of its own success. "Much of its educational role had been adopted by city schools, and its centrality to the development of applied science had been usurped by university research agendas and by other national organizations" (Conn 2010: 154-155). Historian Bruce Sinclair characterizes the institute's educational role as having always been "transitional," as it "pointed out the need for systematic technical training…for the rational exploitation of natural resources, the construction of transportation systems, and the industrial applications of chemistry" (Sinclair 1974: 299). He notes that in the process the institution legitimated an array of more specialized scientific and technical institutions. These specific institutional shifts were the result and cause of a more general trend toward specialization in American life, both in scientific research as well as in professional and occupational settings, resulting in an increasing division of labor. Public school systems organized by grade levels, specialized scientific disciplines institutionalized in universities, specific industrial and corporate laboratories for applied science research – all were increasingly in tension with the broad, non-specialist framework of the initial Franklin Institute and its journal.

These changes helped to set the stage for the Franklin Institute's reinvention and the opening of its new industrial museum in 1934. Another impetus was its cramped and dated facilities, which it had inhabited since its founding. While a committee began to investigate possibilities for moving as early as 1906, only in the 1920s was significant groundwork laid for the new museum. In 1922, the Franklin Institute's board of trustees decided to reestablish the institute as a great industrial museum, along the lines of those in Europe, particularly the Deutsches Museum. To that end, the next year it retreated from its educational efforts, which had come to overlap with formal schooling and vocational training at other institutions, by closing its schools. In 1925 the institute also hired a founding director for the new museum, Howard McClanahan, a Princeton physicist. Then in 1929 it entered into an agreement with the city of Philadelphia to lease land for the new museum. These were the years when Julius Rosenwald and the Chicago Commercial Club were also mobilizing, inspired by Charles Richards' publication of *The Industrial Museum*, galvanizing discussion of the importance of such museums and their absence in the U.S. The Franklin Institute's reinvention via its new industrial museum – today synonymous with the Franklin Institute itself – was a way of staying abreast of the times and of contemporary cultural objectives and needs. (I explore in greater detail the exhibitionary conventions devised to advance these objectives in the next section, on Chicago's MSI.)

Even as the Franklin Institute opened its industrial museum in 1934, however, it continued to assert the possibility of combining the museum's public educational spectacles and "hands-on" science exhibits with professional scientific research conducted "backstage," in affiliated facilities. For example, even as the institute planned for its new building and museum, Philadelphia industrialist Henry Bartol donated $1 million in his will to the institute for a research lab. This bequest resulted in the Bartol Research Foundation, devoted primarily to research in nuclear physics and cosmic radiation and separate from the new museum (from 1928 onward, it was located on Swarthmore College's campus and operated in conjunction with the college). It participated in the mid-20th century trend toward emphasizing "basic science" as a route to applied science, and managed to lure top university faculty to leadership positions – thus establishing itself as a player in the broader scientific field and in the production of scientific knowledge at the time. As Conn writes, "It reveals a great deal about the relationship between museums and their role in the production and dissemination of scientific knowledge that the Franklin Institute could first attract physicists from Princeton and then from Yale to administrative posts" (Conn 2010: 167).

Though the MSI was pulling out of its research activities during these same years, the Franklin Institute's trajectory suggests that such shifts were not the inevitable result of institutional changes in scientific research and the museum field – at least until the later 20th century. Indeed, the Franklin Institute's engagement with scientific research alongside its museum activities would continue several more decades, as will be discussed further in Chapter 5. In its continued emphasis on research, the institute initially shared more in common with natural history museums than with other industrial science museums or later science centers – stemming from their common roots in the 19th century, in an era before the heightened professionalization and specialization of science that would come to characterize the urban-industrial era. Meanwhile industrial science museums would grapple not only with how to reconfigure the exhibitionary conventions of natural history museums, but also with the new urban-industrial context in which visitors increasingly lived and worked, attempting to serve a more diverse "public" than early 19th century museum visitors. Turning now to an examination of Chicago's MSI, I examine some of the ways early U.S. industrial science museums developed exhibitionary conventions to intervene in contemporary urban-industrial built environments and media ecologies. Here I conceive built environments and landscapes as integral to media ecologies, alongside more familiar media such as TV, film, and print media. Below is a table summarizing some of these exhibitionary shifts and the reconfiguring of "rational amusement" at industrial museums.

Reconfiguring "Rational Amusement": From 19th Century Natural History Museums To 20th Century Industrial Science Museums…

	Rational Amusement Pedagogic Elements: Practices and Discourses	***Core Exhibitionary Conventions of Rational Amusement***	***Direct Challenges to Exhibitionary Conventions of Rational Amusement***	***Liminal Exhibitionary Practices: Possible Challenges to Exhibitionary Conventions of Rational Amusement***
19th Century Natural History Museums	***Practice:*** Object Lessons – pedagogy of material culture and firsthand experience, rather than abstractions and books	Regularities: taxonomically and hierarchically ordered artifacts and specimens; e.g.: Linnaean taxonomy, Great Chain of Being	Anomalies, freakish curiosities, *lusus naturae*	Habitat dioramas, including recreated wilderness landscapes
19th Century Natural History Museums	***Discourse:*** Enlightenment discourse emphasizing natural order, individual reason and free will	The natural world as orderly and rational; the new U.S. social order based on the "laws of nature"	Anomalies, freaks and *lusus naturae* as outside the natural order	Suspicion of images and sensuality in relation to reason; perception of wilderness as heathen, uncivilized, chaotic
20th Century Industrial Science Museums	***Practice:*** Emphasis on "real things," rather than texts – especially mechanized, push-button operated exhibits	Initial emphasis on evolutionary taxonomies; later, more emphasis on immersive environments & spectacular exhibits	No equivalent of *lusus naturae* and no clear challenges to rational amusement; habitat dioramas totally accepted	The spectacles and attractions of world's fairs, including their dime museum & amusement park-like midways
20th Century Industrial Science Museums	***Discourse:*** Populist discourse of "hands-on" and experiential learning; but less emphasis on object lessons as exemplifying the "natural order"	The U.S. as a great powerhouse of Yankee ingenuity, technological progress, and industrial civilization; the natural world as natural resources	In urban-industrial world of human-created objects, nothing clearly "outside" the natural order (as *lusus naturae* thought to be); perhaps only sci-fi entities	Industrial museums still aspired to the cultural legitimacy of museums, with higher status than amusement parks; "technological Coney Islands" as new others – but boundaries vaguer

Table 2: Reconfigured Rational Amusement Exhibitionary Practices and Discourses

"The Century of Progress" and Chicago's Museum of Science & Industry

Chicago's Museum of Science & Industry (MSI) opened to the public in its first incarnation in 1933, concurrently with the "Century of Progress" world's fair (1933-34) that marked the city's centennial. Additional sections of the MSI would open throughout the 1930s, particularly the West pavilion in 1938. While planning for the MSI eventually took place in conjunction with planning for the fair, efforts to found the museum had been in motion since 1926, when Chicago philanthropist and businessman Julius Rosenwald, a leading U.S. executive and philanthropist of his day, outlined his plan for an industrial museum at a meeting of the Commercial Club of Chicago. This club included Chicago's industrial elite and the MSI's initial board of trustees formed from its members, following the pattern of late-19th century natural history museums governed by industrial elite trustees. Rosenwald had been turning over the industrial museum idea since a family trip to Munich in 1920, during which his son was thrilled to explore the largest European industrial museum at that time, the Deutsches Museum, known for its working models of machines that could be operated by visitors at the push of a button – an interactive, "hands-on" museum. This museum would become the principal model for the MSI and other contemporary U.S. efforts to found industrial museums. Commercial Club elites also wanted to advance the prestige of Chicago rather than accept its "Second City" status relative to New York, and thought that establishing the nation's first industrial museum was an excellent way to do so. Defending capitalism from its critics via appropriate "industrial education" was yet another purpose of the museum, as touched on above. Though Rosenwald died in 1932, before the MSI opened to the public, his efforts were successful in establishing an industrial science museum that continues today, unlike several other contemporary initiatives to found industrial museums (e.g. The Museum of the Peaceful Arts in New York, and the Smithsonian's proposed National Museum of Engineering and Industry).

After Rosenwald's passing, the most significant figure shaping the initial incarnation of the MSI was Waldemar Kaempffert, the MSI's first director. Kaempffert came to this post with a longstanding interest in the cultural and social histories of science, having previously worked as the science editor at the *New York Times*. Though his tenure at the MSI did not last long – not even through the MSI's opening in 1933 – due to the apparent lack of fit between his ideals and the objectives of MSI trustees, Kaempffert not only authored the MSI's first exhibit guide but also conceived the initial spatial layout of exhibits, established the MSI's ties with the Deutsches Museum, and specified the internal organization and objectives of curatorial staff, among other legacies. Though many of his early efforts were later revamped by the MSI's long-serving and influential president, Lenox Lohr, Kaempffert articulated an initial vision of a U.S. industrial museum that most directly bridged the conventions of natural history and industrial museums in the U.S. Kaempffert established the touchstones that Lohr referenced in defining his own version of an industrial science museum, at a time when science centers were in the offing, and industrial museums increasingly tended to view themselves entirely separately from natural history museums. The discourses and exhibitionary practices that Kaempffert first articulated are thus a pivotal touchstone for analyzing how industrial museums both drew on and departed from natural history museum conventions of exhibition, including by reconfiguring the terms of "rational amusement" to achieve the cultural objectives particular to industrial museums.

First, one of the overarching ways in which Kaempffert and other industrial museum entrepreneurs framed their exhibitionary conventions – and built on the legacies of natural history museums – was to emphasize how industrial museum exhibits helped visitors to transcend the limitations of their everyday built environments to experience distant "natural" settings and "applied science" firsthand, in a variety of recreated industrial scenes. As Kaempffert wrote in the MSI's first exhibit guide, echoing the opening of Richards' book:

> [T]he processes of industry… are largely mysterious because they are complicated and because they are carried on in huge mills and factories to which the public has no access. Machines smelt, pull, twist and forge metal, but only a few engineers and factory employees see them and are familiar with them. These inventions…must be exhibited and explained…Moreover they must be made to work much as they would in their natural industrial surroundings. (Kaempffert 1933)

Kaempffert indicates that the museum framed industrial sites such as factories as if they were "natural settings," akin to distant ecosystems that might appear in habitat dioramas in natural history museums. Exhibits featuring recreated industrial landscapes were thus a kind of material-cultural travel technology, allowing visitors imaginatively to overcome the constraints of their lives beyond museum walls, especially the increased specialization of urban-industrial built environments.[29] Such environments were removed not only from "wilderness" settings, but from many sites of industrial production and applied science as well.

Recreated industrial landscapes might take several forms – for example, as dioramas or as full-size, more immersive environments, depending on the scope of the industrial landscape and/or artifacts represented. Dioramas featured in the early MSI included those showing agricultural harvesting technologies, from horse-drawn plows to contemporary mechanical reapers. As for full-size, more immersive environments, the early MSI's foremost exhibit was its Coal Mine exhibit – modeled after a coal mine exhibit in the Deutsches Museum. The MSI's Coal Mine exhibit, which remains to this day, enabled visitors not only to view from a distance the landscape of the mine's shaft and walls, but to actually descend – physically and imaginatively – into the mine's depths. It was an early immersive environment and "virtual reality" experience in a museum. As Kaempffert wrote:

> Real? It is impossible to distinguish reality from illusion here. The mine-cage and coal-skip appear alternately at three-minute intervals at the top of the head-frame, and skip dumping seven tons of coal which it has raised. Climb the stairs around the head frame and step into the cage. It is the miner's elevator, far older than the elevator that takes you to and from your skyscraper office. The cage seems to drop a distance of 500 feet – the length of the cable. There is a blast of cold air and a musty smell – both inseparable from coal-mining. Ears, eyes, nose, skin – every sense proclaims the coal mine. (Kaempffert 1933: 13)

This journey was intended as an object lesson not only in the source of fuel for the industrial revolution, but in the mechanics of coal mining as well as the principles of geology – thereby demonstrating the apparent seamlessness of "applied science" and "pure science." At the same time, the museum's designers hoped that such immersive environments would provide relatively straightforward messages about the connections between applied science, technological progress, and the comforts of modern life. As Kaempffert continued, after visitors arrived at the "working

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[29] It does seem curious, however, that Kaempffert characterizes mills and factories as places "to which the public has no access," since many people presumably worked in such settings during their non-recreational hours. This statement could be taken as evidence that the MSI's envisioned public initially did not include the working classes of mills and factories, as could Kaempffert's reference to the difference between the Coal Mine's elevator and skyscraper elevators used by visitors.

face of coal" in the exhibit, "You understand now why coal is plentiful and cheap – why much of the old drudgery of winning it with the pick and the drill belongs to the inefficient past" (Kaempffert 1933: 13-14). While these lessons were important, the exhibit also enthralled visitors simply through the sensory experience it provided.

Recreated, "firsthand" industrial experiences also often included push-button operated machines and cut-aways of machines, allowing visitors to view their inner workings. Indeed, push-button operated exhibits were a hallmark of the new MSI and its brand of "interactivity." As an early flyer advertising the MSI put it, "A presentation of scientific and engineering achievements where visitors can push buttons and pull levers to their hearts' content and see and hear the answer to the eternal question of the machine age, 'How and why does it work?' It is a museum of the new age – an age in which things move."[30] Meanwhile Kaempffert describes in the first MSI exhibit guide an imagined visitor's experience:

> Enter the main doorway today and pass into the first court. You see – what? Animation everywhere. Many of the machines have push-buttons and levers. Let the wheels spin around. Here is a gyroscopic turntable that transports you to a realm where forces different from those of ordinary life produce queer effects…Half a dozen different pumps are in action. There are X-ray machines, electric generators, a score of machines for different industrial uses, all so mounted that their operative principles may be studied, usually in action. (Kaempffert 1933: 12)

Such statements and the MSI's emphasis on push-button operated exhibits as pivotal to the "new age" of the machine suggest that techniques such as activating a machine were thought of as a meaningful, populist form of participation in applied science and industry. Moreover, they were not framed as mere entertainment or amusement; the MSI would not be any "technological Coney Island," as Kaempffert put it, but would reconfigure "rational amusement" to include such new exhibitionary techniques.

The MSI and other industrial museums endeavored not only to furnish visitors with firsthand experiences of "applied science," but also to mold these experiences in particular ways, emphasizing particular kinds of order and logic. Various taxonomies were deployed to convey such order – another key way in which the early MSI drew on conventions of natural history museums, even while adapting them for technical and industrial artifacts. Kaempffert was especially preoccupied with taxonomizing. He viewed the taxonomizing of inventions, including industrial machines, as a complicated but potentially achievable and rational enterprise[31] akin to taxonomizing flora and fauna. After his appointment, he set about figuring out such a taxonomy and an organization for the museum as one of his principal projects. In his 1928 "Program of Work for Curators," Kaempffert explains the task at hand: "What interior arrangement is best suited for our purpose can be determined only after we have organized the museum into its major divisions, surveyed the field that belongs to each division, and listed the models and other exhibits that naturally fall within each division…Since the preliminary studies must cover the whole field of technology and industry from antiquity to the present day the staff must work with

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[30] Undated flyer, apparently prior to the MSI's opening in 1933, entitled: "The Museum of Science and Industry: An Institution to Reveal the Technical Ascent of Man."

[31] Though as Kaempffert acknowledged after visiting the Deutsches Museum, "[N]o technical museum in the world has finally solved the problem of classification and arrangement" (Kaempffert 1929: 2). Kaempffert was interested in such a project throughout his career as a science journalist and popularizer, before and after his tenure at the MSI, including as the principal science journalist at *The New York Times*.

the greatest intensity…" (Kaempffert 1928: 1). Kaempffert's initial solution for Chicago's proposed industrial museum, informed by the model of the Deutsches Museum, was an organization into six divisions: 1) Physics, Chemistry, Astronomy; 2) Geology and the Mineral Industries; 3) Agriculture and Forestry; 4) Motive Power; 5) Transportation and Communication; and 6) Civil Engineering and Public Works. Though he acknowledged that, "It was not the intention to adhere to these divisions rigorously, but simply to create the nucleus of an organization which, it was realized, would rapidly expand…[and] some subdivisions will undoubtedly become major divisions"[32] (Kaempffert in MSI 1929: 11).

The MSI's departmental divisions, meanwhile, mapped onto the larger spatial layout of the museum as a whole, institutionalizing in the built environment of the museum taxonomies and classificatory schemas for the exhibition of "applied science." Great effort went into figuring out the MSI's initial spatial layout, including the departments and categories into which the museum space would be organized and exhibits would be displayed. The MSI's spatial layout presented, in material cultural form, "logical sequences" for each department that radiated outward from the Central Rotunda and North Court, which were not designated for any particular department. As later MSI director Philip Fox wrote in 1937:

> The general plan of distribution of space to the various departments of the Museum calls for each to branch out from the Central Rotunda or from the North Court. The exhibits of the several departments are to be so arranged that the visitor following a logical sequence will return to the Central Rotunda or enter a closely related field that will lead again to the center of the building. (Fox in MSI 1937: 1)

Meanwhile the Central Rotunda would feature a periodic table of the elements, as "a great fundamental exhibit 'The Building Blocks of the Universe'" (Fox 1937: 2). Such spatial arrangements suggested a progressive evolutionary framing of science and industry that was repeatedly referred to in the museum's early printed publicity materials as well, such as Kaempffert's article "An Institution to Reveal the Technical Ascent of Man." This partitioning of space and framing of industrial artifacts and knowledge at the MSI constituted a material cultural statement of the intelligibility, unity, and progressive evolution of science and invention in the "machine age," one configured in a single place in a seemingly controlled, rational and coherent way – as in the MSI's 1937 layout (MSI 1937: 2-3).

Significantly, in this layout, "basic scientific knowledge" in chemistry and physics flowed seamlessly into technological and engineering fields such as the mineral industries and aviation. This approach supported the MSI's general frame of science as "applied science" and nature as natural resources. As the MSI's first Curator of Chemistry reflected on these arrangements, "In keeping with the general plan of the enterprise, chemistry will be presented both as a branch of exact and applied science and as a moving economic and social force. Thus, we shall find not only exhibits displaying and explaining the fundamental physical chemistry of matter…but also exhibits wherein drugs, dyes, salts, acids, and a host of other commodities are manufactured or refined" (Ehrenfeld 1930). In this way the MSI's spatial layout separated and

[32] When the MSI finally opened in 1933, Kaempffert's initially proposed taxonomy had already changed, to feature more specialized departments of transportation and split off physics and chemistry, and included curators for eight different departments: 1) Agriculture, Textiles and Forestry; 2) Geology and Mineral Industries; 3) Chemistry; 4) Power; 5) Physics; 6) Automotive Engineering; 7) Architecture and City Development; and 8) Rail Transportation (Kaempffert 1933: 129).

juxtaposed “pure” and “applied” science, while bracketing social relations and the mutual constitution of nature, science and industrial technology in arenas beyond the MSI.

The early MSI’s spatial layout and displays of “the natural world” attempted *both*: 1) to impose taxonomic order and assert interpretive authority over subject matter vis-à-vis visitors, including the ultimate authority of “science” itself; and 2) to provide visitors with engaging, interactive, “firsthand” (literally, hands-on) experiences, intended to encourage public inquiry into the sciences and technologies of industrialization. In these ways, industrial science museums both drew on and departed from the exhibitionary conventions of natural history museums – though often without acknowledging their exhibitionary debts to natural history museums or shared exhibitionary genealogies. This tendency of museums to distance themselves from their pasts and to claim ever “newer” and more “lively” exhibitions continued in other forms in subsequent decades, as industrial museums confronted ever-changing technological artifacts, and museums of all kinds found themselves increasingly in competition with new forms of mass media entertainment with their apparently endless streams of imagery and movement.

Meanwhile the 19th century significance of *lusus naturae* waned entirely, in the context of the reconfigured approach to rational amusement at industrial museums, especially as Kaempffert’s taxonomic efforts and similar approaches fell by the wayside. In a human-made world of “second nature,” nothing was so clearly outside “the natural order” as *lusus naturae* were once thought to be. While science museums would continue to worry about the ambiguous line between science education and “mere entertainment,” as exemplified by later debates over adding IMAX theaters and featuring “blockbuster” exhibits such as Body Worlds, the concept that certain creatures or entities were a priori “freaks of nature,” outside the natural order, lost its potency. Perhaps the closest equivalents to *lusus naturae* at 20th century science museums were entities from science fiction, such as space aliens and hyper-intelligent robots. Such creatures were often part of the utopian, sci-fi sensibility of world’s fairs as well – which tended to recast entities beyond the contemporary “natural order” of things not as monstrous, but as progressive and desirable.

The World’s Fair Returns to the Museum: Lenox Lohr & the “Newest” MSI

As mentioned above, Kaempffert’s tenure at the MSI did not last. As the Depression unfolded and finances became tighter for MSI trustees, monetary constraints became more apparent, even as Kaempffert appeared to plan as grandly as ever. According to Jay Pridmore, “Kaempffert was eager to expand his staff – at seeming cross-purposes with the newly budget-minded trustees. By early 1930, Kaempffert envisioned a total of 600 separate exhibits to be ready for the opening of the Museum. To accomplish this he would need a staff of 200....” (Pridmore 1996: 47). This was a far larger staff than the board of trustees was comfortable with, given the financial context of the times. Earlier doubts about Kaempffert’s administrative qualifications for his post resurfaced (his previous career was in science journalism, not business or administration). Board members raised questions about his leadership and board president Rufus Abbott kept a close watch on financial details. Meanwhile Kaempffert felt increasingly at odds with the board when a director of International Harvester joined the MSI’s board of trustees, even as planning for an exhibit on farm equipment was in progress and executives from International Harvester insisted that their company invented the modern farm tractor, though curatorial research proved otherwise. Kaempffert’s commitments were to science and technology education above all, rather than to fiscal management or financial expediency. Then toward the end of 1930, Abbott divided the MSI’s administation into curatorial, public relations and business divisions – each with their own assistant director, who would report both to Kaempffert and the MSI's board of trustees. Kaempffert was offended by this arrangement, and took steps to return to his previous job at the *New York Times* – resigning from the MSI on January 2, 1933, approximately 6 months before it opened to the public. For the rest of the decade, the MSI would continue to take shape more or less along the lines laid out by Kaempffert and his curatorial staff, though not on the grand scale to which Kaempffert had aspired.

The MSI began to shift more significantly in 1940, when the board elected Lenox Lohr as MSI president. Lohr's association with the museum began in the period leading up to the 1933 Century of Progress world's fair and the MSI's initial public opening, as Lohr was Vice President and General Manager of the fair. The announcement of his appointment highlights this managerial experience, noting that after the fair Lohr had become President of the National Broadcasting Company (NBC), "and has in that period developed that internationally known organization into a world force in radio entertainment and education" (MSI 1940: 2). The announcement also notes his service in the World War I, as a Major in the Army Corps of Engineers, and generally highlights his energy and wide worldly experience – experiences distinct from those that Kaempffert had brought to the MSI. While Kaempffert was more of a public intellectual, Lohr was more the showman – and the changes Lohr made to the MSI's staff, collections and exhibitionary conventions reflected that basic difference. Lohr's approach to science museum exhibition would also prove to be the wave of the future, as industrial science museums and later science-technology centers hewed closer to their world's fair roots than to natural history museum conventions.

While Kaempffert began his tenure at the MSI preoccupied with appropriate taxonomies for illuminating the history of invention, one of Lohr's first moves was to dismiss a raft of curators and the MSI's director, among other staff, many of whom specialized in precisely such taxonomizing, historical knowledge, and scholarly expertise. Lohr cited budgetary reasons for the dismissals, which also served to free up resources for him to deploy other exhibitionary approaches – to re-envision the museum along the lines he found most compelling. In many regards, this meant making the MSI more like a world's fair, to attract crowds from Chicago as well as from further afield. Rather than the Deutsches Museum, the Century of Progress was Lohr's point of reference. As Lohr said in an August 14, 1940 *Chicago Daily News* article: "I visualize the institution not as just a limited Chicago museum, but as a great national museum, a show, in which science and industry will live as dramatic things…" Meanwhile a September 15, 1940 article in the *Delta Democrat Times*, "Musty Museums Passe, Says Rosenwald Director," began: "Museums must have the color and eye appeal of a world's fair to attract attention and compete for public interest in 1940, believes Major Lennox Lohr, new, revolutionary-minded director of the Rosenwald Museum of Science and Industry here. Lohr…has completed plans for 're-vitalizing' the huge, drab and undramatic Rosenwald Museum, dedicated to a living portrayal of American industrial progress." Lohr reportedly explained, "There is intense drama in the function of science and industry as pictures in the museum, but it needs pointing up, bally-hoo." Again, the trope of life – and the determination to create a "livelier" and "more animated" museum – was used to outline the projected changes in the MSI's exhibits and ethos. This time, rather than natural history museums being framed as passé, the MSI's recent, initial incarnation was framed as musty and dated, compared with world's fairs. As Lohr put it in the *Chicago Daily News*:

> From Chicago's Century of Progress, of which I was general manager, we learned that people are most attracted to those exhibits which they may

> operate themselves…Where, at the fair we had exhibits which spectators operated by pushbuttons, in the museum we hope to have many exhibits in which they will actually take a real part in operating.

Apparently forgotten were the ways in which world's fairs had adapted techniques from museums, and vice versa.

Lohr's transformation of the MSI also emphasized displaying the present and future as part of becoming a "livelier" museum, rather than the past and historical lineages of invention as Kaempffert had done – the latter being another convention of natural history museums, bound up in the very name as well as the process of biological evolution. As Lohr explained, "The day of the old fashioned type of industrial museum, in which most of the exhibits pertained to another day, is gone." (*Chicago Daily News*, August 14, 1940) One of the ironies is that the "old fashioned type of industrial museum" was really not so old, particularly the MSI in the U.S. This point suggests one of the core tensions in the whole premise of industrial science museums: traditionally, museums were places to preserve things of abiding value – yet in the contemporary world, it often seems that all around, "all that is solid melts into air," as Marx put it. This transitory dynamic seems especially acute and especially unavoidable in industrial museums, since their artifacts and subject matter are intertwined with the creative destruction of industrial capitalism, as much or more than any transcendent "laws of science" or "laws of nature." As Luca Peressut observes, "The times of science and technology, bound to the dynamics of changes in research and production, and the times of the museum, bound to consolidation and reflection, can only partially coincide. That of the scientific museum has been a curious condition, from its very birth: that of showing 'progress' by being constantly overtaken, speaking of modernity while constantly slipping into history" (Peressut 1998: 16). At the MSI, Lohr seemed to understand what he was up against, however, and had a strategy for dealing with the situation: acquire a series of spectacular, iconic exhibits that could stand the test of time – including a German U-boat and a grand fairytale castle from the silent film star Colleen Moore. Some of these exhibits, such as the fairytale castle, might not even be relevant to displaying industrial science.

Intertwined with these exhibitionary conventions – displaying spectacular, "livelier" attractions reminiscent of world's fairs and focusing on the present and future rather than the past – was an emphasis on industrial corporations as sources of invention and "progress." Unlike Kaempffert, who had balked at having an International Harvester executive join the MSI's board of trustees, Lohr was enthusiastic about industrial and corporate participation in the MSI and its exhibits. He was also skilled at recruiting companies to participate. As an MSI "Museum Information" sheet from Lohr's tenure puts it:

> Since 1940 industry has become a full time partner in the Museum. Under the direction of Major Lenox R. Lohr, Museum president, a program of industrial participation has been developed which has received the full cooperation and support of American industrial enterprise. Industrial exhibits to date represent an investment of more than ten million dollars. Each year sees this investment increase both in terms of new exhibits and in the maintenance, additions and changes of older exhibits.

The companies participating in the MSI in these ways included: the Aluminum Company of America; Bakelite Corporation; Commonwealth Edison Company; General Motors Corporation; B. F. Goodrich Company; International Harvester Company; Shell Oil Company; Standard Oil Company; Radio Corporation of America; Sears, Roebuck & Company; American Telephone &

Telegraph Company, and United Air Lines – to name some of the most recognizable.[33] Partnering with such corporations through its "industrial participation program" enabled the MSI to display artifacts such as combines and the latest in communications technology, as at a world's fair, which might otherwise be out of reach.

"The Museum Goes to War": World War II & Beyond

Due partly to Lohr's army service and on-going military ties, the MSI collected an array of military technology exhibits, beyond anything at the Franklin Institute or any other industrial science museum – a distinction that persists to this day. This trend started during World War II and continued for decades afterward. As a 1943 report, "The Museum Goes to War," articulates the relationship between the MSI and the war effort:

> [T]he Museum of Science and Industry went to war along with the rest of the nation. Machine tools, metal working, petroleum, coal, steel, agriculture – these are among the important things in a nation at war. And it is these things to which the Museum is devoted. Around the great dome of the Museum of Science and Industry is inscribed its theme: 'Science Discerns the Laws of Nature; Industry Applies Them to the Needs of Man.' The needs of man have changed from peacetime needs to those of the greatest war effort that mankind has ever known. And it is in science and industry that the hope – and conviction – of civilization rests. (Chicago Commercial Club 1943: 1-2)

The report, by the Chicago Commercial Club's Committee on the MSI, goes on to describe the ways in which specific "War Exhibits are Prepared" (Chicago Commercial Club 1943: 2) – including submarines, mine-sweepers, torpedo tubes, and trench mortars – as well as programs of technical education designed specifically for those in the armed forces. Indeed, during this period, the museum became part of the trainees' program of the Sixth Corps Army Signal Corps Training School (Chicago Commercial Club 1943: 4), with groups also visiting from the Navy Aviation Machinists School at Navy Pier. These groups would study the construction and operation of torpedoes, the collection of ship models ("not pretty mantel decorations – but accurately made for study purposes and unexcelled by any collection in the Middle West"), as well as the basic machine tools in the MSI's metal working section, among other exhibits. After the war, however, these programs ended and visitors encountered the MSI's military exhibits more as spectators looking to be impressed and entertained, attracted to machinery they might otherwise encounter only in movies and newsreels.

In some ways, World War II not only ushered in a trend toward exhibiting military artifacts and technologies at the MSI, but also set the stage for the "golden era" of American industrial capitalism, with its burgeoning middle class lifestyles. It set the stage for the social world that the MSI would engage through its exhibits and other programming, seeking to advance consumer capitalist values in relation to science and industry, as well as democracy. As the 1943 report reflected on "Science and Industry – and the American Way":

> [T]he Museum's efforts do not stop with the dissemination of technical information…it tells the broader story of science and industry. There is probably nothing which so completely distinguished the United States among

[33] Years later, a young employee of Ralph Nader's Public Citizen would investigate corporate influence on science museum exhibits, including the MSI, and publish his findings in a white paper which became somewhat infamous among science museum employees of the day.

> the nations of the world when it went to war a year ago as its high standard of living. With six percent of the world's population, we had 50 percent of the world's telephones…We had enough automobiles to take everybody in the country riding at the same time. Hosiery and furniture alike were being made from coal, water, and air; dresses from wood; farm fertilizers from the atmosphere; camphor from pine stumps. These existing proofs of the effectiveness of the combined efforts of science and industry operating under the rules of that institution so firmly imbedded in American tradition and known as private enterprise, individual initiative, or the American way of work and life, are not achievements to be gazed at in incomprehension…If American industry, aided by scientific research, has constantly placed within the consumer's reach a better way of living, has helped to give the world the fullest life in recorded history, a responsibility exists to tell that story…It must be told to clarify past misunderstandings, to prevent further misunderstandings, which, if allowed to grow, might undermine that combination of science and industry functioning under the aegis of a democracy. (Chicago Commercial Club 1943: 9-10)

World War II ushered in the consumer capitalist era discussed further in Chapter 5, during which science education would take on new meanings in the context of the Cold War and the space race, and new types of science museums would proliferate, reaching out to new publics along lines partly foreshadowed above.

Meanwhile, industrial science museums such as the MSI, drawing on both natural history and mechanical arts traditions of collection and display, were implicated in the problem of "civilizing the machine in the garden" of the U.S. – or achieving a sustainable balance between conservation and exploitation of nature. The country had become an urban-industrial nation-state with more industrial engineers than Deist natural historians. Yet the socially constructed nature of "wilderness areas" and their relationship to urban-industrial landscapes was generally not addressed in science museums. Thus by the 20th century, the cultural problem of "civilizing the machine in the garden" was not resolved as much as bracketed at science museums. As such, the deeper conflicts among participants in the science museum field – and by extension, science – were not engaged. These conflicts included relations among sciences oriented toward conservation versus exploitation of "the natural world." I will discuss these themes further in Chapter 5 and in my concluding reflections in Chapter 6.

Chapter 5: The Science Center Movement & Smorgasbords of Learning Props: Local "Hands-On" Knowledge amidst Deindustrialization and Ecological Crises

Post-War Science Museum Reinventions: Legacies of the Industrial Museums Movement

A quotation on the Web site of the Association of Science Technology Centers (ASTC) reads: "Science centers provide firsthand experience and the opportunity to develop intuitions about the natural world." It is a statement reminiscent of Charles Wilson Peale's ideas in the late 18th century about creating a science museum to open a "Book of Nature" to his fellow citizens, in order to school them not only in natural orders but the new U.S.'s republican social order, supposedly grounded in natural law. Yet the ASTC, founded in 1973, is organized around institutions so at odds with older museum models that these new institutions often drop the name "museum" entirely, preferring to be known as science centers. This chapter analyzes the rise of science centers as a new type of late-20th century science museum, in relation to earlier science museum conventions, contemporary media ecologies, as well as broader national landscaping projects with which these science museums were intertwined. In particular, this chapter examines the post-war reinvention of the Boston Society of Natural History as the Boston Museum of Science, as well as the influence of San Francisco's Exploratorium, founded in 1969, as part of an institution-building project some refer to as a "science center movement" in the 1970s and 1980s. It analyzes the rapid growth of science centers in the U.S., compared with earlier industrial science museums. The chapter analyzes how science centers both drew on and departed from earlier science museum conventions, particularly their breaks with natural history and industrial science museums' emphasis on collections and taxonomies. At the same time, all of these science museums shared a genealogy of object lessons as a means of gaining so-called "firsthand experience" and "the opportunity to develop intuitions about the natural world," per the ASTC. In the process, this chapter looks at the ways in which science centers, like industrial science museums before them, again reconfigured the terms of "rational amusement"– embracing a madcap, smorgasbord ethos in which popular culture was welcomed into science museums rather than held at bay.

This chapter argues that these reconfigurations represented new forms of science boundary-work in the public sphere. More specifically, this chapter argues that late 20th century science center museums participated in science boundary-work in part by creating spaces in which "the natural world" seemed open to multifaceted, interactive, populist exploration and questioning by visiting publics, without a sense of the larger landscapes of which exhibits were a part, including the questions not being asked. In particular, the reconfigured science museum field of the late 20th century persistently ignored the contradictions of framing science as both instrumental to *and* transcendent of society, part of a separate "natural world." Thus, even as more science museum exhibits have addressed environmental issues and sustainability concerns, especially climate change, they have tended to ignore the contradictory messages across exhibits and the STEM (Science, Technology, Engineering, Mathematics) field as a whole. Ultimately, this chapter discusses the ways in which the problem of "civilizing the machine in the garden" – balancing industrial exploitation and conservation – was not resolved, but arguably had become more fraught by the end of the 20th century. It became more fraught as deindustrialization accelerated, and "technology" replaced "industry" in science museums' discourse – embedded in new narratives of globalization, STEM education, and national economic competition.

Natural History Museums in the Later 20th Century:
The Boston Natural History Museum Reinvented As the Boston Museum of Science

In setting the stage to discuss science centers and their transformative effects on the U.S. science museum field, it is helpful to recall the two primary types of science museums preceding science centers such as the Exploratorium: natural history museums and industrial science museums. Though varied in their own rights, these two science museum types demarcated the range and the main conventions of science museum exhibition in the immediate post-war era. On the one hand, natural history museums continued to frame scientific knowledge in terms of the preindustrial natural world, through the exhibition of specimens and ethnographic artifacts, as well as habitat dioramas. On the other hand, a small number of industrial science museums framed scientific knowledge in terms of its applications, particularly in the context of the industrial revolution. Many of these industrial science museums had emerged in conjunction with world's fairs and took their cultural bearings from them – the foremost U.S. example being Chicago's Museum of Science and Industry.

In a sense, these two types of science museums embodied different facets of the contradictory science boundary-work that appeared throughout the 20th century: professional scientists framed science both as integral and useful to society, via its applications, and as autonomous and transcendent of society, inhabiting a distinct realm of nature and "pure science." Meanwhile tropes of enchantment and wonder, though subsumed under a dominant discourse of rationality, were selectively deployed at both types of museums as part of this persistent double boundary-work. Both types of science museums also emphasized collections and taxonomic display of artifacts, but interspersed with more interactive and immersive displays, including habitat dioramas and the MSI's Coal Mine exhibit. Science centers would build on and define themselves in relation to these distinct paradigms and exhibitionary tropes.

Before the Exploratorium and other science center museums arrived on the scene, the still relatively new industrial science museums had begun to disrupt the earlier framings of "science" at natural history museums such that old institutional identities were in flux in the post-war era – opening new possibilities that would contribute to the science center movement. Various older science museums were seeking new ways of displaying "the natural world" and science to publics, especially in light of the on-going need to remain appealing to publics that had diverse options for entertainment and leisure. Just as industrial science museum entrepreneurs at the Chicago MSI and beyond had framed natural history museums as "dusty" and stultified, so did many natural history museum leaders perceive their institutions as in need of renewal.

One of the foremost examples of this quest for renewal is the Boston Society of Natural History and its New England Museum of Natural History, which director Bradford Washburn renamed and reinvented during the 1940s as the Boston Museum of Science. The name change indicated the museum's shift from featuring not only the pre-industrial world of natural history, but also the applied scientific knowledge of the industrial era – from the principles of thermodynamics to the operations of everyday technologies. Washburn conveyed this broad sense of science in his 1947 annual report:

> Our new Museum should comprise not only exhibits of birds, animals, insects, and minerals, but it should include a Planetarium and it should have space for constantly changing industrial exhibits to show the inseparable relationship between nature and industries that have made this part of America famous. To construct an old-style static museum in this fast-moving age would be

> suicidal. A name such as The Boston Museum of Science would vastly broaden our popular appeal. Such a name is in a way a definite outgrowth of our old name… Science is today the all-inclusive and dramatic term that Natural History was a few generations ago. A change to this brief modern name would do a vast amount to stir the public with regard to our future plans. It would certainly result in a far broader appeal to the corporations of this region without whose support and interest it will be exceedingly difficult, if not impossible, to raise sufficient funds for the erection and maintenance of a new building. (Washburn, as quoted in Rock 1989: 47-48)

These ideas about the breadth and dynamism of scientific knowledge, and related exhibitionary conventions, would lay key groundwork for the emergence and spread of science center museums – even as the industrial museum idea that had supplanted the earlier natural history frame was itself being supplanted. Indeed, Washburn and the Boston Museum of Science would later be leading players in the formation of the ASTC and the science center movement.

The reinvention of the Boston Society of Natural History and its New England Museum of Natural History did not spring only or initially from a broadened conception of "science," however, but rather from the exigencies of renewing an institution begun in the 19th century that in many ways remained modeled on late 19th century natural history museums – hands-off and taxonomic, though interspersed with habitat dioramas. Indeed, Washburn, renowned as an explorer and mountain climber, was hired in 1939 as the fifth director with a mandate to renew the museum. As he reflected back on these days in a speech at the museum's annual meeting in 1974, his 35th anniversary as director, he said:

> When [the Boston Society of Natural History] had opened our [museum] building on Berkeley Street in 1864, we were the finest museum in America…[T]he passage of 74 years had resulted in our sliding from the top of the ladder almost to the bottom…Our budget was $42,000. Our operating deficit was $12,200. Our attendance had been 26,000 visitors in that entire year! (Washburn 1974: 1)

Washburn went on to say that "[T]hree alternatives clearly existed": 1) to continue with the status quo, and somehow make ends meet, as the museum had in the past; 2) to sell the property and give the BSNH's collections and financial assets to Harvard, while terminating the 108-year-old BSNH itself; or 3) "to review our assets, our liabilities and our program in light of the trends and needs of the day, and then to revitalize the Museum to meet these needs realistically – even if it meant moving to a new location and dramatically changing the character of its program" (Washburn 1974: 2). After initially trying to work within the museum framework he had inherited in the New England Museum of Natural History, it was this third option that Washburn and the Museum's Board of Trustees ultimately chose.

The Museum's transformation unfolded in fits and starts, however, as Washburn explored the contemporary science museum field by visiting a range of science museums throughout Europe and the U.S., seeking options for reviving the BSNH's natural history museum. These investigations were reminiscent of trips taken by industrial museum entrepreneurs as they sought to found or reinvent their own institutions in the 1930s – the main difference being that Washburn's touchstones were found in the U.S. as well as Europe. As Washburn reported, "I had [by 1945] visited the new museum in Rochester, New York, as well as the Franklin Institute and the great Museum of Science and Industry in Chicago. They added a new dimension to our master plan. This must be a Museum of <u>Science</u>, not just a Museum of

Natural History" (Washburn 1974: 3). These reflections underscore the influence of the principal U.S. industrial science museums on Washburn's reinvention of the BSNH's natural history museum. He also sounded much like the MSI's rotunda in a May 12, 1948 memorandum to trustees when he proposed that the new museum would "show the multiplicity of ways in which man, with the help of science, has adapted the raw materials of the world to meet his ever-increasing and complex daily needs" (Washburn as quoted in Rock 1989: 58). In addition, like these U.S. industrial science museums, Washburn situated the reinvented Boston Museum of Science in the genealogy of European industrial museums, particularly the Deutsches Museum, and contrasted them with "dead or dying" natural history museums. As Washburn wrote in his 1978-1979 annual report, just before his retirement:

> The old nature repositoriums – vast three-dimensional dictionaries – were dead or dying, and the wave of the future was clearly in a new direction. The days of dusty cases, grumpy guards, and lengthy labels were drawing to an end. We were clearly at the threshold of an Era of Involvement. This era had started at Munich's extraordinary Deutshes Museum, founded by Oskar von Miller and Carl Zeiss in 1903; but only two museums in America were following this lead: Julius Rosenwald's Museum of Science and Industry in Chicago, and Philadelphia's Franklin Institute, both concentrating entirely on physical and applied science. (as quoted in Rock 1989: 215)

Thus contemporary science museums should emphasize "involvement" – a word with populist connotations that would in later years be used alongside "interactivity," "participation" and "hands-on science." In light of these assessments, after serving in the Army and Air Force between 1942 and 1945, Washburn began taking action to reinvent the New England Museum of Natural History as the Boston Museum of Science. In 1948, Washburn successfully negotiated the procurement of unused land on the Charles River – later known as "Science Park" – on which to locate a new, larger building for a reinvented Museum of Science. The new museum opened in stages between 1950 and 1953, with additional facilities and buildings opening in subsequent years.

In many respects, Washburn was responding to a trend among science museums across the U.S., in which many museums founded as natural history museums had expanded to more comprehensive framings of science and nature – principally, by including the applied sciences, industrial science and technology. "If such a program can be achieved by New York, Chicago, Buffalo, Denver, San Francisco, San Diego, Rochester, Detroit, and Minneapolis, we can succeed here in Boston…. Above all, let us set our sights for a preliminary goal within our reach. If our Museum is small, compact, and the best of its sort, its future growth into our ultimate ideal is certain" (Washburn, as quoted in Rock 1989: 32). In listing these places, Washburn was referencing both industrial science museums founded as comprehensive "science museums" – as in Chicago and New York – as well as natural history museums that had already been expanded to include physics, chemistry and the applied sciences – as in Buffalo, Minneapolis and Denver.

Washburn also acknowledged his indebtedness to leading natural history museums that had continued to innovate as natural history museums in the 20th century – first and foremost New York's American Museum of Natural History (AMNH). In particular, he acknowledged the influence of the AMNH's ever more grand habitat dioramas, most of which were constructed in the early 20th century. As Washburn sketched a version of science museum history:

> The earliest science museums had been <u>dictionaries</u> of the world we live in – collecting, storing, cataloging, but, above all, simply <u>identifying</u> and <u>protecting</u> the things of Nature. Our eminent and immediate forebears, Henry Fairfield Osbourne and Roy Chapman Andres of New York's great American Museum of Natural History had dramatically changed the thrust of public science education in the first third of this century by making their museums a vast and absorbing <u>textbook</u> of nature. Instead of just presenting an orderly <u>dictionary</u> of Natural History, they led an intellectual revolution which made exhibits show the vital <u>interrelationships</u> of nature. Instead of just showing thousands of well-labeled birds on perches, they focused on how birds adapt to their environment, how they migrate, what they eat, how they nest – and how their lives <u>relate to their environment</u>. The now-common word <u>Ecology</u> underlay this movement, and it was constantly in our minds thirty years ago, as the plans for this new Museum were being laid. (Washburn 1974: 3)

Washburn's emphasis here on habitat dioramas presenting an "ecological" understanding of specimens and the natural world, with its own scientific value, was a refrain heard frequently among earlier natural history museum staff advocating a move beyond taxonomic ordering of specimens in exhibits. What was distinctive in Washburn's emphasis on ecology here – and a departure from the earlier industrial science museum entrepreneurs – was that he did not direct a natural history museum, but a museum whose primary touchstones for reform had been industrial science museums. In other words, Boston's Museum of Science and Washburn's approach to reinventing it had drawn on both industrial and ecological understandings of science and nature, unlike the early MSI and Franklin Institute. The complexity and potential contradictions of these touchstones are discussed further in the next section, and at the end of the chapter, as part of the cultural problem of "civilizing the machine in the garden."

Exhibitionary Conventions: From Taxonomic Ordering to Science Smorgasbords

In terms of exhibitionary conventions, a core shift as the New England Museum of Natural History became the Boston Museum of Science was that the conventional taxonomic approach to displaying natural history specimens, which defined and dominated the earlier museum, was replaced by habitat dioramas of "New England Life Zones" as well as an overall "smorgasbord" approach to presenting all the sciences, industry and nature. Though initially the new museum attempted an internal spatial organization that sounded similar to the early MSI, demarcating the museum's East and West Wings as the Hall of Nature and the Hall of Physical and Applied Sciences, respectively, this organization was found to be too rigid, according to an article in the AAM's *Museum News* (Harrison 1960: 16). Subsequently, "smorgasbord" became one of the buzzwords used repeatedly by Washburn and in Museum of Science publications to describe the new museum's approach to exhibition, connoting its emphasis on a dynamic mix of subjects and their interrelationships. A 1969 *Reader's Digest* article about the museum, entitled "<u>This Is a Museum?</u>" reported:

> On the theory that people do not come to museums for orderly learning, but rather to wander and browse, the museum has abandoned the time-honored 'textbook' technique of devoting halls to chemistry, geology or some other particular science, for what it calls a 'smorgasbord' approach. The displays are artfully mixed to create a continual element of surprise. For example, after watching steel balls gyrate in eccentric, accelerating orbits around a wide-

> mouthed funnel to illustrate Kepler's Laws of Planetary Motion, the visitor comes to a diorama showing how the Egyptian pyramids were built, a cloud chamber in which particles from outer space streak across a black screen, and a rotating carrousel of lives snakes common to New England. (Schiller 1969: 226)

The Boston Museum of Science has thus come to resemble Chicago's MSI, with its atmosphere more like a world's fair – or carnival, as the *Reader's Digest* article described it – than the supposedly stodgy, earlier natural history museums. Its "smorgasbord" spatial organization and eclectic exhibitionary approach were key features of this new incarnation, alongside its emphasis – like earlier industrial science museums – on "hands-on" exhibits. As the *Reader's Digest* article described, "[E]xhibits talk, move and invite you to 'push,' 'pull,' 'listen,' 'feel' and operate them" (Schiller 1969: 226). These conventions would go on to characterize later science center museums as well.

The implications of such a "smorgasbord" organization were and are complex, however, as discussed further at the end of this chapter. On one level, such a smorgasbord organization was simply more flexible and hence convenient for museum staff, particularly given the wide world of scientific developments with which they were now trying to engage. In addition, as mentioned above, a smorgasbord organization arguably facilitated more dynamic visitor experiences, with "a continual element of surprise." Washburn also presented it as a way to avoid overwhelming visitors, saying in his 1974 speech, "Instead of bewildering totality, we decided that we must present a <u>sampling</u> of science – a stimulating smorgasbord – ever-changing, ever focusing our exhibits squarely upon the needs and issues of the day" (Washburn 1974: 4). In addition, and more problematically, museum staff also associated a smorgasbord approach to exhibition with conveying to visitors a sense of the "interrelationships" among the sciences and the interrelationships among various exhibits. As the 1960 *Museum News* article put it, "As to combining exhibits in the various sciences, the Museum staff is convinced by its ten-year experience of the soundness of this original concept. It has also come to feel that awareness of the interrelationships among the sciences is perhaps the most important point the Museum can make, and it is positive that the variety of the Museum's exhibits is a significant factor in attracting and holding visitor attention" (Harrison 1960: 16). The article is vague as to the specific "interrelationships" among the sciences that seemed most crucial to the staff, however. In other documents, Washburn and others sometime refer to this sense of interrelationship as "ecology." For example, as Washburn wrote in 1948, "The rather new study of ecology is the fundamental concept of the modern museum: to show the host of unavoidable interrelations between the many fascinating components of any given life zone" (Washburn as quoted in Rock 1989: 57-58). As mentioned above, Washburn also said that the word ecology "was constantly in our minds thirty years ago, as the plans for this new Museum were being laid" (Washburn 1974: 3). However, absent in these references to ecology is a discussion of the complexity and potential contradictions of the "interrelationships" among the various sciences, particularly the applied sciences of industry and conservation-oriented environmental sciences. Instead, the smorgasbord approach to exhibition arguably fostered an ethos of fun and engagement, in which an infinite variety of questions seemed to be addressed, but where crucial questions about the political-economic dimensions of ecology were usually not – or never – asked.

A Shift Away from Collections and Research

The Boston Museum of Science's new incarnation also shifted its emphasis decisively and permanently away from research and collections, and toward public education that no longer emphasized artifacts and collections. This institutional and exhibitionary shift, too, would go on to influence the science center movement – and was a trend that would be taken much further at many science centers, particularly those that never had any collections to begin with. Indeed, it is the presence or absence of collections that most decisively marks the difference between science *museums*, on the one hand, and science *centers*, on the other – though I analyze science centers as types of science museums. Washburn himself sometimes refers to the new Boston Museum of Science as a science center when he emphasizes its identity beyond its collections, saying, "In modern museums of science and natural history, the primary emphasis is no longer on exhibits, but on public service. Our new Museum will be a live, active nature and science center, not a static museum in the old sense of the word. The caliber of a museum of today is no longer judged by the tonnage of its collections, but by its degree of usefulness as a vital part of the recreational and educational framework of its community" (Washburn as quoted in Rock 1989: 57-58). Later 20th century science museums increasingly reinvented themselves – or were founded – to serve new purposes and constituencies, particularly children and families with an array of new leisure and media options; deemphasizing collections was another core shift in science museums' exhibitionary conventions that accompanied these institutional changes. *Reader's Digest* gestured toward this new media ecology in praising the reinvented Boston Museum of Science: "Such attractions have made Boston's Museum of Science one of New England's biggest box-office hits" (Schiller 1969: 227). Museums' past reference points were no longer necessarily the most relevant ones in a post-war U.S. world of new media and communication landscapes, built environments, and publics. The Exploratorium in San Francisco – arguably the leading science center museum world-wide – would build on and amplify these trends, while distinguishing itself among U.S. science museums through its emphasis on the arts and perceptual experience.

Foundations of the Science Center Movement:
The NSF, "Basic Research," and the Cold War Context of U.S. Science Education Reform

The shifts at the Boston Museum of Science took place against the backdrop of the Cold War, particularly the post-Sputnik push for improved U.S. science education to meet the perceived national challenges of the day. So, on the one hand, Washburn's reinvention of the New England Museum of Natural History was spurred by the advent of new types of "science museums" and absorbing the legacies of the earlier industrial science museum movement. On the other hand, Washburn's activities played out during a particular period of U.S. history, when scientific research, education and curricular reform assumed new significance. It was a period ripe for mobilization by science educators, in other words, including those at science museums. This was especially true as science museums increasingly defined themselves in terms of their role in public education, rather than as stewards of rare collections oriented toward scholarly research. In particular, the National Science Foundation (NSF), founded in 1950, gradually became a new ally for those in the science museum field, and the eventual science center movement. Another key ally in those early years was the Atomic Energy Commission – though it would not forge an abiding relationship with the science museum field, as would the NSF.

During these post-war years, "science" was in the process of being reframed in the public sphere, as it had been in the transition from natural history to industrial museums and exhibitions. In particular, a key shift in framing "science," compared to the industrial museum movement period, is that “applied science” and the industrial story were muted by a new federal emphasis on “basic research.” The most influential voice in articulating this paradigm was Vannevar Bush, who in 1945 published a report, “Science – The Endless Frontier,” which argued for the autonomy of the scientific community to pursue basic research, defined as research “performed without thought of practical ends” than “results in general knowledge and understanding of nature” (Rudolph 2002: 41). This approach to research was institutionalized a few years later at the new NSF, such that research would be publicly funded as never before, but guided by scientists’ prerogatives, rather than public input. To make this platform more politically palatable, Bush and NSF officials came to argue that, “technological applications, such as those successfully developed during the war, depended directly on the reservoir of fundamental scientific knowledge so far accumulated” (Rudolph 2002: 41). It was the dawning of the era of Big Science, in other words – or large-scale scientific research funded by the U.S. government. Historian John L. Rudolph, in his book *Scientists in the Classroom: The Cold War Reconstruction of American Science Education*, emphasizes that World War II fundamentally changed the nature of U.S. scientific research and its relations with both the federal government and the public, complicating scientists’ attempts to maintain both their funding and their autonomy. As he writes:

> The conflation in the public mind of science and technology was the most vexing of the challenges facing the scientific community. The new instrumental technologies scientists developed during the war brought them generous government patronage and national status, which they welcomed. But the success of these technologies also worked against their efforts in the postwar period to maintain public funding for research that seemed at times far removed from the country’s day-today economic and social needs….[T]hey had to work hard to overcome public resistance to the privileged position science and scientists seemed poised to claim in the new era. Their efforts centered on carefully distinguishing basic research from technological development and cultivating a perception of American science as inherently democratic in its organizational structure and virtuous in its pursuit of truth. (Rudolph 2002: 34-35)

Rudolph goes on to argue that these themes and perspectives on science became central to two of the principal initiatives to reform science curricula in formal educational settings in the postwar period: those of the Physical Science Study Committee (PSSC), begun in 1956, and the Biological Science Curriculum Study (BSCS), begun in 1958 and modeled after the PSSC. PSSC scientists would also form the Elementary Science Study (ESS), according to Wendy Pollock of the ASTC, and “These scientists and curriculum reformers would, as advisors and friends, influence the science centers emerging from the 1960s on” (Pollock Sept./Oct. 2007: 3).

While the practical, instrumental significance of science was far from forgotten during this period, the public framing of science during the years leading up to the science center movement, including in new science curricula, was one that reinforced the autonomy of scientific research. Daniel Greenberg has described this postwar development as supporting a “politics of pure science,” in which “pure science regularly strives to define itself and to distinguish its essential qualities from those of other technical activities” (Greenberg 1967; 1999: 10). Vannevar Bush had himself referred to the least practical areas of science as “the purest realms” (Rudolph 2002: 41), though ultimately there might be manifold military and commercial applications. This framing of science performs a kind of boundary-work. While science centers tend to emphasize their interactive, hands-on exhibits as the mainstays of their pedagogic innovations, the move at many new science center museums to frame science as autonomous from society and from instrumental objectives was another significant shift away from the earlier industrial science museums. It accorded with the NSF's "Basic Research" prerogative and "Public Understanding of Science" activities, as discussed further below. Science centers' move away from collections of artifacts tended to reflect and facilitate such a reframing of science. This reframing enabled a subtle form of boundary-work, less obvious than boundary-work to distance late-19th century natural history museums from the "humbugs" and pseudo-science of P. T. Barnum, or the move by earlier industrial science museums to distance themselves from supposedly stodgy natural history museums. A twist on this framing of "pure science" was, in some ways, particularly prominent at the Exploratorium.

The Exploratorium: Frank Oppenheimer's Museum of Science, Art & Human Perception

San Francisco's Exploratorium, founded by physicist Frank Oppenheimer and opened to the public in 1969, was one of the leading players in the science center movement, and has become one of the most influential science museums worldwide. Part of this renown stemmed from the visionary and charismatic character of Oppenheimer, described by some in the science museum field as a kind of guru. Oppenheimer had traveled a circuitous, varied path to founding the Exploratorium – marked by both scientific and political events, as well as an abiding interest in the arts. Like his older brother, J. Robert Oppenheimer, Frank Oppenheimer earned a Ph.D. in physics from the California Institute of Technology. During his time in California, he also became engaged to a Berkeley economics graduate student, Jaquenette (Jackie) Quann, who was active in the Young Communist League. Like her, he joined the American Communist Party not long after they married in 1936 – against the backdrop of fascism's rise in Europe and left-wing counter-mobilizations, including by communist groups. J. Robert Oppenheimer recommended against both commitments, but Frank went his own way. During World War II, Frank went to work with his brother on the Manhattan Project. After the war, however, Frank Oppenheimer's association with the Communist Party came back to haunt him. He became a target of McCarthyism, lost his job as a physics professor at the University of Minnesota, and was prevented from taking a similar post elsewhere. Unable to leave the U.S., he and Jackie sold a Van Gogh painting that belonged to Frank's family, and with the proceeds they bought a cattle ranch in Colorado. They ranched there for ten years, during which time Frank became president of the local cattle ranchers association, and eventually started teaching high school physics. He would take students on field trips to the local dump to find "props," such as springs and rubber belts, for physics demonstrations. These experiences shaped the pedagogic approach that he later deployed at the Exploratorium, where he emphasized prop-based exhibits of scientific phenomena – rather than collections or technologies of "applied science."

As McCarthyism waned, Oppenheimer began exploring ways to return to public education, drawing on his scientific background. His job as a high school physics teacher in Pagosa Springs, CO eventually led to his appointment as a physics professor at the University of Colorado, Boulder. Then, while on a Guggenheim fellowship at University College in London – a period during which he visited science museums throughout Europe, including the Science Museum of London, the Deutsches Museum, and the Palace of Discovery in Paris – Oppenheimer began formulating his ideas for the Exploratorium. He intended it to be a new kind of science museum, based on "interactivity" not only via push-button operated machines, but also via exploration, experimentation and non-directive learning. He envisioned a place where visitors could discover scientific principles for themselves, with the aid of props, as in a kind of laboratory. He returned to the U.S. and began to work toward this vision. After speaking at a 1966 conference on Museums and Education sponsored by the Smithsonian Institution, he was offered the chance to plan a new branch of the Smithsonian to carry out his ideas, but he turned down the invitation in order to focus on his own "San Francisco project." The burgeoning counter-culture and the avant-garde ferment of the San Francisco Bay Area were among his attractions to the area, after also considering New York, where he had grown up. As he articulated his vision in 1968, in an article entitled "Rationale for a Science Museum":

> The phenomena of basic science which have become the raw material of invention are not easily accessible by the direct and unaided observation of nature…There have been many attempts to bridge the gap between the experts and the laymen. The attempts have involved books, magazine articles, television programs and general science courses in schools. But such attempts, although valuable, are at a disadvantage because they lack props; they require apparatus which people can see and handle and which display phenomena which people can turn on and off and vary at will. Explaining science and technology without props can resemble an attempt to tell what it is like to swim without ever letting a person near the water. (Oppenheimer 1968: 206)

Oppenheimer thus emphasized props as a means of facilitating visitors' own discoveries about basic scientific phenonmena, particularly their role in fostering interactivity – "apparatus which people can see and handle and which display phenomena which people can turn on and off and vary at will." He also underscored science museums' unique capacity to foster such interactivity, compared with formal science education in classrooms, print media, or mass media such as TV. To him, science museums were places uniquely suited to bringing publics together with scientific phenomena, in a direct and open-ended fashion.

In 1969, the Exploratorium opened to the public in the Palace of Fine Arts in San Francisco, a building constructed originally for the 1915 Panama-Pacific Exhibition, thereby continuing the tradition of synergy between science museums and world's fairs. While the Exploratorium drew on earlier science museum models, in various ways it represented a unique synthesis of exhibitionary conventions and innovations in engaging publics with "science" – especially in its lack of emphasis on collections, and its incorporation of an artists-in-residence program from its earliest days. The Exploratorium's unique synthesis is suggested by the museum's description as a "museum of science, art and human perception," which dovetailed with Oppenheimer's emphasis on presenting visitors with "phenomena of basic science." In brief, Oppenheimer conceived of human perception as the common ground of both the sciences and the arts – and science and art as both important means of understanding perceptual phenomena. As he wrote in a 1979 article in *The Humanist*, entitled "Aesthetics and the Right Answer":

> Art and science are very different, but they both spring from cultivated perceptual sensitivity. They both rest on a base of acute pattern recognition. At the simplest level, artists and scientists alike make it possible for people to appreciate patterns which they were either unable to distinguish, or which they had learned to ignore in order to cope with the complexity of their daily lives. One can look at hills without noticing that they have a shape until a Cezanne becomes preoccupied with the form of Mont St. Victoire…. Similarly, one can observe the planets rise and set without becoming aware, as Kepler did, that

> they are moving in ellipses about the sun… Darwin and Faraday, Freud and Marx, as well as Bach and Webern, Giotto and Klee, Shakespeare and Pinter, have all sensitized us to patterns which we might otherwise have missed. (Oppenheimer 1979: 1)

As this passage suggests, Oppenheimer had wide-ranging knowledge across disciplines and fields – an eclecticism and perceptual acuity that stood out both among other scientists as well as those in the science museum field. The Exploratorium's uniqueness as a science museum stemmed partly from Oppenheimer's unique vision. From the beginning, he put these perceptions – of the interrelatedness of the arts and sciences – into practice in the organization of the museum and its exhibits, which he and Exploratorium staff conceived and constructed. By 1972, the museum featured nearly 200 exhibits; by 1980 there were more than 400; and by 1990 approximately 700 – nearly all made on-site in the Exploratorium workshop (Danilov 1990). These exhibits ranged from the Bernoulli Blower to the Brine Shrimp Ballet. As Oppenheimer explained in his earlier "Rationale for a Science Museum," under the subheading "A Possible Poem Of Organization For Such a Science Museum":

> A form of organization which could help fulfill the underlying purpose of the museum would involve introducing the various areas of science and technology with sections dealing with the psychology of perception and the artistry associated with the various areas of perception…[For example,] [t]he section on hearing might be introduced with a collection of musical instruments. (Oppenheimer 1968: 207)

As the Exploratorium took shape, it was guided by these early idea-sketches and "poems of organization." The museum's contemporary section on auditory phenomena, for example, includes artists' sound installations as well as glass pipes of varying lengths to enable visitors to experience how air columns of different air pressures produce different tones. The Exploratorium's artists-in-residence program has also maintained an active presence of artists in the museum, in the process underscoring the importance and relevance of the arts to perception – including "scientific" perception, inquiry and analysis. As Oppenheimer articulated in the Exploratorium's reprint of his "Aesthetics and the Right Answer" article, at a reunion of artists who had participated in the program, "Art is very much an integral part of what we want people to experience here. If you're going to know about nature, you have to know about how people react to and feel about nature. I think that's what artists communicate" (Oppenheimer 1979: 1).

While many appreciated – and even lionized – Oppenheimer as an individual with a unique vision of human perception in relation to the arts and sciences, less has been made of the social, historical and educational contexts that informed his vision. In these regards, in addition to his family's appreciation of the arts, Oppenheimer's pre-war education as a physicist was particularly significant. The war was in many ways a watershed for physics research and physicists. Prior to the Manhattan project, physics was a less instrumental affair, approached more as a humanistic inquiry – a style that Oppenheimer epitomized. As Hilde Hein (1990) writes in her book *The Exploratorium: Museum as Laboratory*:

> [By 1959, Oppenheimer] found that the climate of academic physics had greatly altered during his exile. Previously, he had felt he was working in a community of fellow enthusiasts to advance the understanding of the physical world. [Now]…Science had become a means to practical achievement. Only a few devotees still perceived it as a liberal art and an enterprise of consuming intellectual interest. Public recognition of the need for scientists had

> transformed the conception of what science was. Even in the eyes of many of its practitioners, science had become a lucrative profession and had ceased to be a form of humanistic learning. (Hein 1990: 13-14)

In other words, Oppenheimer's sensibility – or habitus, as Bourdieu would say – as a physicist had been forged at an earlier historical juncture, when physics was less technocratic and professional physicists less careerist and narrowly focused. His approach to physics, in part, reflected and refracted this earlier period – including the wide-ranging interests and associations he brought to inquiring into and interpreting physical phenomena. In contrast, Oppenheimer found himself alienated by the new academic norms of the 1960s, which facilitated his devotion to creating his own world of inquiry at the Exploratorium.

Though the post-war framing of "pure science" was particularly prominent at the Exploratorium, given its emphasis on perceptual phenomena rather than artifacts and applied science, the role and status of the arts at the Exploratorium was unique. In this regard, the Exploratorium stood out both among science museums and in the broader field of science education and public science discourse. Oppenheimer's approach to "pure science" was not the same as Vannevar Bush's "endless frontier" of 1945. In bridging the arts and sciences, Oppenheimer's approach engaged in a kind of "boundary-play" (Nippert-Eng 2005) that subverted broader patterns of boundary-work oriented toward demarcating these realms. As the science center movement gradually institutionalized and the broader science museum field grew increasingly rationalized, according to the instrumental logics of the NSF and corporate sponsors, the Exploratorium's emphasis on the common ground of the arts and sciences remained a node of alternative, enchanted, more playful logics.

"The Science Center Movement" and the Founding of the Association of Science-Technology Centers (ASTC)

While the Exploratorium was the most prominent and novel of the new science museums to form during the 1960s, it joined the company of others that were gradually coalescing into the group that would rally around a new definition of "museum," in the U.S. and beyond. These institutions included the Seattle Pacific Science Center, formed after the 1962 world's fair; the New York Hall of Science, formed after the 1964 world's fair; the Fernbank Science Center in Atlanta, opened in 1967; and the Lawrence Hall of Science in Berkeley, founded in 1968. These new science center museums, which deemphasized or entirely abandoned collections, along with the U.S. industrial museums opened in the 1930s, began to organize in the early 1970s to form a professional association to advance their mission and their common interests. They felt a need for advocacy particularly vis-à-vis the American Association of Museums (AAM), as well as the NSF's Public Understanding of Science initiatives. The NSF was problematic because it did not yet fund informal science education, but instead focused on formal science education. As for the AAM, it was devoted to collections-based museums and defined "museums" as institutions in terms of collecting and preserving collections. Thus among science museums, natural history museums alone qualified as museums according to contemporary AAM criteria.

An ally in science centers' organizing efforts was the Information and Exhibits Division of the Atomic Energy Commission (AEC), chaired by Courtland Randall, who had also overseen the U.S. science exhibition at the 1962 Seattle world's fair. Randall's goal of advancing public appreciation of science dovetailed with the objectives of the new science museums and with initiatives to reform science curricula in the context of the Cold War. Anticipating this synergy, in 1971 Randall wrote to the directors of these new science center museums and invited them to attend a museum conference in Oak Ridge to:

> [E]xamine how science museums and agencies of the Federal Government can combine forces at a time when public support for science and technology appears to decline…. The science museums selected for this conference have commonality apart from most natural history museums and also apart from university museums. At recent conferences among more general museum groupings the span of interests has seemed too great for cooperation. It is possible that our get-together may lead to some new relationship. (Randall 1971)

In response, on April 22nd and 23rd 1971, 16 science museum directors met in Tennessee, at the Oak Ridge Associated Universities, to discuss whether and how to establish an alternative to the AAM, to create a group more focused on their objectives and institutional characteristics. This group included both Bradford Washburn and Frank Oppenheimer. In 1973, 23 founding members established the Association of Science-Technology Centers (ASTC), which today is the largest association of science museums in the U.S., if not the world (ASTC includes international members as well). The NSF helped out with $75,000 for initial operating support, including the launch of ASTC's traveling exhibits program, and would continue to help out with grants in subsequent years. Founding ASTC members included the Exploratorium, Boston's Museum of Science, the Franklin Institute Science Museum and Chicago's Museum of Science and Industry, among others.[34]

The new science center movement – and a proliferation of science center museums – would take off as the earlier industrial science museum movement had not. According to the ASTC:

> Throughout the late 1980s and 1990s, the science center idea took hold around the world. ASTC had 27 members in 1974, 170 members in 1984, 438 members in 1994, and has approximately 540 today, including more than 420 operating or developing science centers and museums. ASTC is the largest organization of interactive science centers in the world and has members in 40 countries. In addition to science centers, members also include planetariums and space theaters, natural history and children's museums, aquariums and zoos, and related organizations and professional associations. (ASTC 2006: 247)

Thus the ASTC has grown exponentially, with science centers proliferating throughout the 1970s, 1980s and 1990s – with longtime professionals in the field referring to the 1970s and 1980s as the "science center movement" years. The rapid growth of science centers in the U.S.,

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[34] According to the ASTC, its 23 founding members were: American Museum of Atomic Energy (Oak Ridge, TN); Buhl Planetarium and Institute of Popular Science (Pittsburgh, PA); California Museum of Science and Industry (Los Angeles, CA); Center of Science and Industry (Columbus, OH); Cranbrook Institute of Science (Bloomfield Hills, MI); Dallas Health and Science Museum (Dallas, TX); Des Moines Center of Science and Industry (Des Moines, IA); The Exploratorium (San Francisco, CA); Fort Worth Museum of Science and Industry (Fort Worth, TX); Franklin Institute Science Museum and Planetarium (Philadelphia, PA); Hall of Science of the City of New York (New York, NY); Lawrence Hall of Science (Berkeley, CA); Milwaukee Public Museum (Milwaukee, WI); Museum of Science, Boston (Boston, MA); Museum of Science and Industry (Chicago, IL); Ontario Science Centre (Toronto, Ontario); Oregon Museum of Science and Industry (Portland, OR); Pacific Science Center (Seattle, WA); Rochester Museum and Science Center (Rochester, NY); and Science Museum of Minnesota (Saint Paul, MN).

compared with earlier industrial science museums, was facilitated by three main factors: 1) science centers' de-emphasis on collections, particularly of rare and historical artifacts, easing the logistical and financial burdens of opening new institutions; 2) funding from the U.S. government, particularly the NSF, to the ASTC as well as individual science museums and science museum consortia, mobilized around a framework of advancing "public understanding of science"; and 3) growing demand for such science centers by cities and communities, including bandwagon effects as science centers proliferated. Across the U.S., science centers became part of communities' taken-for-granted cultural infrastructure. Later, science centers sometimes became the basis for hoped-for revitalizations of surrounding urban areas as well. Thus, compared with the industrial museums movement, the science center movement was able to mobilize more stakeholders committed to "public understanding of science," around institutions with lower start-up costs. At the same time, it built on the legacies and breakthroughs of the industrial museums movement, shifting museums' exhibitionary conventions as well as the framing of "science" at museums. The science center movement also gained momentum during a time of U.S. post-war economic growth and expansion – in sharp contrast to the Depression that marked the culmination of the industrial museum movement years. As for the AAM, in 1976 it changed its definition of "museum" and criteria for museum accreditation, such that museums no longer needed to own collections of tangible objects of intrinsic value to be considered museums. The ASTC's Victor Danilov was pivotal to advancing the new AAM criteria. In 1982, the AAM awarded Frank Oppenheimer its Award for Distinguished Service to Museums – though when the Exploratorium was founded in 1969, it had not been eligible for AAM membership. Table 1 below provides a schematic view of the diversified science museum field of the late 20th century.

Late 20th c. Science Museums: Founders & Organizational Types	***Intended Audiences***	***Exhibitionary Conventions I: Artifact Display***	***Exhibitionary Conventions II: Internal Spatial Order***	***External Spatial Order: Geographic Contexts Beyond Museum***
Reinvented Natural History Museums I (e.g. Boston Museum of Natural History → Boston Museum of Science)	Broad publics, especially children and families	Broader array of artifacts and exhibits, covering physics, chemistry & technology as well as natural history	Smorgasbords, though often combined with continued separation of natural history from other sections	Increasing deindustrialization of Fordist urban-industrial order; suburbanization; push for economic revitalization via cultural institutions
Reinvented Natural History Museums II (e.g. AMNH or CAS, becoming more grand in reapproaching research and/or public exhibition)	Broad publics, often catering to a wider age range (i.e. more adults) than other late 20th c. science museums	Emphasis on public education & research at leading museums; separate research & exhibition collections; some glass cases, but more dioramas & immersive displays, including interactives	Linnaean taxonomy & evolutionary narratives persist; anthropological collections less prominent or reframed; *lusus naturae* sometimes welcomed back as blockbuster exhibits	Increasing deindustrialization of Fordist urban-industrial order; suburbanization; climate change and declining biodiversity, as industrial capitalism alters "the natural world" beyond museum walls
Reinvented Industrial Museums (e.g. MSI and Franklin), which are in many ways subsumed by the Science Center Movement	Broad publics, as cultural consumers more than producers; increasingly oriented toward children and families	Shift from taxonomies & collections toward recreated landscapes & immersive environments, as well as "props" and interactives	Smorgasbords; some research at Franklin up until 1980s, but in general, emphasis on "hands-on" exhibits; discursive shift from industry → technology	Increasing deindustrialization of Fordist urban-industrial order; suburbanization; science museums framed as part of urban cultural industries & tourist infrastructures
Science Center Museums	Broad publics, especially children and families; though museums increasingly feature evening programs to attract adult audiences	Little to no emphasis on collections or research (except visitor studies), but instead on learning "props" & interactives (increasingly digital over time)	Smorgasbords; growing focus on technology rather than industrialization as "applied science"; *lusus naturae* in blockbusters & IMAX	Increasing deindustrialization of Fordist urban-industrial order; suburbanization; Cold War consolidation of overseas spheres of influence, giving way to neoliberal globalization

Chapter 5 Table 1: 20th c. Science Museum Exhibition Types, Stakeholders & Exhibitionary Conventions

Professionalization, Institutionalization & Standardization: The ASTC, NSF & Exploratorium Cookbooks

Over time, the science center movement became more professionalized and institutionalized, both as a cause and consequence of the rapid growth of science center museums. This professionalization and institutionalization tended to be accompanied by greater standardization – of exhibits, pedagogic approaches, and programs – as museums shared resources, funding streams and "best practices," in a variety of forms. In particular, the ASTC and NSF supported initiatives across the broader science center field, from conferences and workshops to traveling exhibits, while the Exploratorium exerted a powerful influence on the science museum field through its exhibit "cookbooks," which contained guides to exhibit-making. As an associate of the NSF's Informal Science Education (ISE) program described this process in an interview:

> [The NSF has] really helped to professionalize the field over the years which grew up very much as a mom and pop field because every new science center was created independently by its own set of community supporters…So when I got here the thinking was how can we continue to professionalize the field and advance the field, as opposed to constantly reinventing things, which has sort of been the history of science centers. (Interviewee #1 2008)

The gradual growth of the relationship between the NSF and broader science museum field helped to professionalize the field in part through standardization, to avoiding overlapping efforts and build on existing successes. In addition, this person emphasized the singular status of the Exploratorium in influencing the science museum field, "Really to a large degree [each set of community supporters] recreated a science center in its own image in a particular community – many based on the Exploratorium, some based on other models, but mostly the Exploratorium" (Interviewee #1 2008).

One ASTC associate shared these reflections on the science center movement and its institutionalization in an interview:

> [The science center movement] is a very democratic movement in spirit. That's something that the field has prided itself on and a dimension along which it's distinguished itself from art museums, that it's not curator-driven, it's not about high-status and privilege… and that spirit that said everybody in the society needs to know something about science and needs to participate in the culture of science and not be shut out from that, that's been extremely important in this field and what I think distinguishes it…and again maybe why that word 'movement' seems appropriate…or it used to. The word 'industry' came in there somewhere along the line, in the 1990s, and that was a change…. (Interviewee #2 2008)

This statement underscores not only the increasing professionalization of science centers over time, but also their growth as an industry. In particular, science centers came to frame themselves not only as educational institutions, but also as part of the urban culture industry. Throughout the 1980s and 1990s, this growth and identification as an industry rather than a movement was often accompanied by greater orientation toward business metrics and practices. Driven by financial exigencies, these orientations often went against the grain of the science center movement's initial idealism, particularly as new forms of mass media came to compete with science centers, as discussed further in the section on new media ecologies.

Beyond these national institutions, the Exploratorium has played a significant role in influencing the broader science museum field through its exhibit "cookbooks." Long-time Exploratorium employee Robert Semper, who began working at the museum in 1977, reports that visitors to the museum – including other museum professionals – would often wish they could in some way transport their experiences back home to share with others. Hence, in 1975, the Exploratorium created the Exploratorium Cookbook as an "important dissemination tool…designed to help science centers construct educational interactive exhibitry" (Semper 2006: 254). These Cookbooks, of which there are now three volumes, feature "recipes" for constructing popular exhibits based on those Exploratorium employees have created in the museum's exhibit workshop since its opening. The first Cookbook, funded by an NSF grant, contained 82 such recipes. According to Semper, its intended audience included not only museum employees and exhibit developers, but other science educators as well:

> The original book was developed in loose-leaf form so that teachers could buy a single recipe for a class project. The Cookbooks have been used by many developing science centers all over the world. Over 10,000 copies have been sold to date [as of 2006], and the Exploratorium still sells over 100 copies of each volume per year, twenty-five years after their initial production. (Semper 2006: 254)

The Exploratorium's Cookbooks have helped to spread its influence – and exhibits – far and wide. Yet Semper emphasizes that other science museums have often interpreted the recipes in their own ways, using them as catalysts for thinking about exhibit design rather than using them as blueprints. "The straightforward nature of the design principles helped many smaller museums adopt a do-it-yourself exhibit development philosophy and realize that they could develop an exciting environment for learning" (Semper 2006: 254). Still, many exhibits developed at the Exploratorium can be found in science museums across the U.S. and beyond, and the Cookbooks have been a key mechanism of that influence. For example, one of the first exhibits developed by Oppenheimer, the Bernoulli Blower, based on a similar demonstration by vacuum cleaner salesmen in department stores in the 1950s, is now found in very similar incarnations around the world, from Seattle's Pacific Science Center, to the National Technical Museum in Prague, Czech Republic, to the Yapollo Science Center in Trinidad (http://www.exploratorium.edu/books/bernoulli/; accessed February 2012). The Bernoulli Blower is recipe #83 in Cookbook II.

Science Education Discourses from the Cold War to an Era of Globalization: From Public Understanding of Science to "Free Choice" Informal Science Education

As the science center movement grew more professionalized and institutionalized, particular logics animated the growth and rationalization of the field – orientations which changed over time. The field shifted over the years from a Cold War discourse of "public understanding of science" to a discourse of "free-choice," informal learning in the context of so-called "knowledge societies" and globalization. This shift in discourse and its institutionalization took place not only at hubs such as the ASTC, NSF and Exploratorium, but in a broader array of museums, funding sources and educational contexts. These sites constituted what has become known as the field of informal science education (ISE). This field frames itself explicitly and implicitly in contrast to formal science education, as institutionalized in K-12 educational settings and universities. It encompasses not only science museums but an array of other media and sites – television programming, zoos, aquaria, botanical gardens – through which publics may be exposed to educational experiences regarding the natural world, science and technology. The NSF describes the objectives of ISE in the following synopsis: “The [NSF] ISE program supports innovation in anywhere, anytime, lifelong learning, through investments in research, development, infrastructure, and capacity-building for STEM learning outside formal school settings” (http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5361; accessed February 2012). Thus the field emphasizes ISE as part of “lifelong learning” that is ideally envisioned as pervasive throughout contemporary “learning societies.” A touchstone ISE initiative, founded by the NSF in 2007 and located at ASTC offices, is the Center for the Advancement of Informal Science Education (CAISE). This center is intended to bolster the infrastructure of the ISE field, including by providing resources and catalyzing conversations among STEM researchers and ISE professionals (http://caise.insci.org/about-caise; accessed February 2012).

The field of ISE has in many respects taken up the mantle of earlier, Cold War era “public understanding of science” initiatives – though the latter discursive framework is still active in many contexts, including in ways that overlap with the field of ISE. However, the NSF’s ISE program has replaced its earlier Public Understanding of Science program, which initially funded the science museum field, and over time the science museum field as a whole has begun to use ISE as a phrase with less baggage to describe its overarching enterprise. Unlike “public understanding of science” – which can imply a “deficit model” for the relation between publics and science, with publics framed as lacking scientific knowledge – ISE connotes mainly the settings or media through which public science education is to take place, outside of schools. In emphasizing the “informal,” ISE is also often characterized as part of voluntary, “free choice learning” (Falk 2006), which is in turn discursively situated in a “learning society.” Yet despite this discursive shift in some quarters – at the NSF, in STEM policy circles, and at science museums – talk continues about public science literacy and, increasingly, technological literacy, in the context of “knowledge societies.” At the same time, the lofty objectives of the ISE field remain in tension with museums’ need to compete with commercial entertainment in the “new economy.”

From Industrial Science to Technology: The National Center for Technological Literacy & the Nanoscale Informal Science Education (NISE) Network

Another significant shift from the era of the industrial museums movement to the science center movement was the move away from an emphasis on applied science as “industry” and industrialization, and toward an emphasis on applied science as “technology.” The name of the ASTC itself embodies this shift. This change is indicative of broader shifts in U.S. political economy between the early 20th century and late 20th century, from an “old economy” of Fordist production and industry, to a “new economy” of post-Fordist production. In brief, Fordist production emphasized standardization and mass production in industrial manufacturing, with assembly lines of workers each playing a part in a company’s division of labor. While this system was pioneered in Ford’s car manufacturing factories in the early 20th century – while Ford was conceiving his own industrial museum, which eventually emphasized history – it did not fully develop to characterize the broader U.S. economy until after World War II. According to Ankie Hoogvelt, “Ford’s invention was so crucial in shaping the postwar political economy that in much social science literature today this political economy is named after him” (Hoogvelt 1997: 92). Thus the period referred to as “Fordism” by political economists and economic historians are the decades after the war, up until the 1970s.

The 1970s and 1980s were pivotal years not only for the science center movement, but for this shift from a Fordist to a post-Fordist political economy. The very characteristics that had made Fordism initially successful as a system of mass production eventually led to contradictions that resulted in overproduction, and hence job losses and factory closures. According to Hoogvelt, the system's relative rigidity and dependence on large-scale production mean that, "The mass production system cannot cope flexibly with either cyclical recessions, or increased competition, or changing market tastes" (Hoogvelt 1997: 93). As other countries' economies recovered or developed in the postwar years, increased global economic competition, in combination with cyclical downturns, altered the viability of Fordism. Post-Fordist production thereby came to emphasize flexibility and customization, rather than mass production, often with devastating consequences for workers and communities. As Fantasia and Voss write:

> With contingency as its leitmotif, the 'new economy' has come to represent…an economic sector largely able to establish its own rules without having to defer to 'past practices,' to overcome union bargaining structures, or to dismantle the prophylactic mechanisms of state regulation (deregulation representing an act of state as surely as taxation or war making). Within this sector contingency has been elevated to a virtue, and no one has paid much attention to the extent to which the dot.com boom was built on a foundation of low wages and transitory jobs. (Fantasia and Voss 2004: 7)

Post-Fordist production was accompanied by changing patterns of capital investment and manufacturing deindustrialization as well. Beginning in the 1970s and accelerating in the 1980s, former leading U.S. industrial cities experienced a trend toward capital flight – to the suburbs, other parts of the U.S. (particularly the Sunbelt South), and outside the U.S. Indeed, the South Side neighborhoods surrounding the U.S.'s first industrial science museum, the MSI in Chicago, are contoured by capital disinvestment, combined with white flight (with the exception of the somewhat more integrated Hyde Park neighborhood of the University of Chicago). Thus, given many science museums' emphasis on "applied science" and technology, an elephant in the room during the science center movement years was the phenomenon of deindustrialization. In recent years, various science museum initiatives have highlighted the importance of "technological literacy" and engineering. Implicitly or explicitly, these initiatives speak to the new challenges faced by U.S. workers and communities, given the long-term trend of manufacturing deindustrialization, as described further below.

The National Center for Technological Literacy (NCTL):
Technological Literacy, Engineering, "Innovation," and Global Economic Competition

In 2004, the Boston Museum of Science launched a new National Center for Technological Literacy (NCTL): (http://www.mos.org/nctl/about.php; accessed 2/17/12). This initiative was articulated with growing national concern about the adequacy of the U.S.'s STEM education infrastructure and "technological literacy," particularly in engineering, given the challenges of economic globalization and increasing international competition. As a 2008 white paper about the NCTL, "Engineering the K-12 Curriculum for Technology Innovation," by museum president and director – and former dean of Tufts University's engineering school – Ioannis Miaoulis, began:

> With an economy in crisis and a workforce at risk, educating the nation's future engineers and scientists and advancing technological literacy are more important than ever. We need a strong engineering workforce to remain

> competitive. To maintain our country's vitality and security, we must expand students' understanding of technology and engineering and widen the pipeline to careers in these fields so that a diverse array of talented students can pursue them. The goal of the Museum of Science, Boston [through the NCTL] is to introduce engineering and technology to schools and at least one science center or informal education organization in every state by 2015. (Miaoulis 2008: 1)

Miaoulis first presented this paper at a 2008 National Science and Technology Summit at Oak Ridge National Laboratory, Tennessee, convened by the U.S. Office of Science and Technology Policy, as called for by the 2007 America COMPETES Act. The summit took place at the same location – fraught with symbolic significance in terms of national security – where science museum leaders and representatives of the Atomic Energy Commission had met decades earlier to form the ASTC and initiate a broader science center movement, to push for greater "public science literacy." This time, however, the U.S.'s global political-economic context had shifted from the Cold War to a context of economic globalization and competition – contoured by neoliberal policies of trade liberalization, privatization and deregulation. Supporting the NCTL's mission, for example, a September 2009 report by the National Academy of Engineering (NAE) and National Research Council (NRC), "Engineering in K-12 Education: Understanding the Status and Improving the Prospects," concludes that K-12 engineering education:

> [M]ay improve student learning and achievement in science and mathematics, increase awareness of engineering and the work of engineers, boost youth interest in pursuing engineering as a career, and increase the technological literacy of all students. The teaching of STEM subjects in U.S. schools must be improved in order to retain U.S. competitiveness in the global economy and to develop a workforce with the knowledge and skills to address technical and technological issues. (http://www.mos.org/nctl/about.php; accessed February 2012)

National policy-makers had redefined engineering as central to national competitiveness, and emphasized the role of STEM education in advancing this form of security in a globalized economy.

The discursive shift at the NCTL from "science literacy" to "technological literacy" registers this changed context. Indeed, Miaoulis repeatedly distinguishes these two types of literacy in his white paper, arguing that "K-12 math and science education has received a lot of attention, while K-12 technology and engineering education has been largely overlooked" (Miaoulis 2008: 1). He then goes on to frame the NCTL's educational initiatives to advance "technological literacy" in terms of a particular historical narrative. As he puts it:

> The problem is that the school science curricula still focus more on the natural, not the human-made or technological, world, and have taught little or no engineering. The beauty of engineering is that it is the connector that uses science and math to create the technological innovations that facilitate daily experience. Nineteenth century society was largely agrarian. No phones, automobiles, or computers. Obviously, our world has changed but most curricula have not, leaving a huge gap in students' learning…We need to add technology and engineering as standard subjects in U.S. public schools. (Miaoulis 2008: 1)

Thus Miaoulis frames the NCTL's activities as if they were responding to a curricular gap between a 19th century, agrarian U.S. and a 21st century, technological U.S. This framing ignores the history of industrialization and waves of industrial and technical education reform that took place throughout the late 19th and 20th centuries, including at earlier museums, as well as Cold War era initiatives to reform science curricula, at that same site. This frame also neglects the industrial museum movement of the 1920s and 1930s, and the more recent science center movement. In so doing, the frame above neglects the broader "spatial orders" and changing historical geographies with which these science museum movements were intertwined – including the trend away from urban industrialization and toward deindustrialization in many parts of the U.S. from the 1970s onward. It also leaves out the burgeoning relevance of research on the natural world that pertains to ecological crises – including climate change and declining biodiversity – that standard industrial development and its technologies have precipitated. In ignoring or glossing over these historical contexts and relationships, the frame articulated above contributes to obscuring the contradictions of the NCTL and similar initiatives to foster "technological literacy." It dehistoricizes the broader patterns of social relations – including corporate power and capital flight – with which contemporary U.S. engineering and "innovation" are enmeshed.

"Hands-on" exhibits have quite different meanings depending on the broader political-economic contexts and geographies – both national and international – in which they are historically situated. Often, such hands-on exhibits are intended not only to convey "information," but also to prefigure and encourage particular occupational trajectories or other types of participation in society. While earlier mechanics' institutes and industrial museums might have featured occupations like makers of machine parts or automobile assembly-line workers, these careers are less likely or impossible for visitors to contemporary science museums, such as the Boston Museum of Science. In any case, if technical occupations are not part of leading, cutting-edge growth industries, they are not the overarching occupational trajectories that the NCTL seeks to foster, given its objective of contributing to greater national competitiveness in the global economy.

Neglecting the long genealogy of "hands-on" education at science museums, dating at least to the 19th century, can contribute to blackboxing not only occupational relations, but pedagogic discourses of "hands-on" learning and their contemporary baggage of assumptions about children and human nature. As Miaoulis voices some of these assumptions, "[E]ngineering is rich in hands-on experiences. Children are born engineers, fascinated with building and taking things apart to see how they work. Describing these activities as engineering can help them develop positive associations with the field" (Miaoulis 2008: 1). These assumptions inform the NCTL's exhibits and programs to promote technological literacy, including fostering K-12 curricular reform to include engineering.

The Nanoscale Informal Science Education (NISE) Network

The foremost example of a nation-wide collaborative initiative at science museums framed principally in terms of "technology" – rather than industry or industrial science – is the Nanoscale Informal Science Education Network (NISE Net), launched in 2005 and funded by the NSF as "a national community of researchers and informal science educators dedicated to fostering public awareness, engagement, and understanding of nanoscale science, engineering, and technology" (NISE Web site: http://www.nisenet.org/about; accessed Feb. 15 2012). The NISE Network is a decentralized science and policy information network led by 14 museums and universities across the U.S. – the primary leaders being the Boston Museum of Science, the Exploratorium, and the Science Museum of Minnesota. Research institutions, museums, other informal science organizations, as well as individuals "interested in communicating with the public about nanoscale research are welcomed and encouraged to join" (http://www.nisenet.org/about; accessed February 2012). According to the Web site, in response to the question, "Why was it formed?":

> Advances in nanoscale science, engineering, and technology are revolutionizing medicine, computing, materials science, energy production, and manufacturing. Yet, to the general public, these advances can be invisible or difficult to understand. The NISE Network was created to engage the public in advances in nanoscale research, to capture the imagination of young people who may subsequently choose careers in nanoscale science or technology, and to foster new partnerships among research institutions and informal science centers.

In other words, the NISE Network deploys and recycles much of the same rhetoric used by science museums, the informal science education sector, and other science popularizers throughout the 20th century: scientific progress in given fields has outpaced public exposure and understanding, and there is a need to help people catch up – and to encourage them to consider becoming scientists working on similar developments in the future.

Given the potential economic importance of nanotechnology, however, a special program to "sell" nanotechnology to the general public (as well as to attract workers to the field) may reflect a more political agenda. Nanotechnology is not just any technology or domain of technological development, but an arena of vast anticipated commercialization of science and technology in the future. Moreover, in its scale and in the radicalism of its changes to the fabric of the material world, nanotechnology is reminiscent of biotechnology – a fraught and contested area of "public understanding," from the vantage of many in the fields of scientific research and education. Speaking to both issues, a NISE Network associate said in an interview:

> One of the reasons that NSF and I guess the government in general is so interested in funding nanotechnology public engagement projects is because they don't want a backlash reaction. Many states are really pushing nanotech as an economic initiative, especially for areas that have economies that have moved out or, you know, have developed beyond that. So the Rust Belt, you know…. If you're looking at a knowledge economy in general, maybe some of that projected or feared backlash…well I know that a lot of it is because of the GMO situation in Europe and the fact that there was not a programmatic public engagement effort. So, for instance, the European community funded a two-year nano dialogue, which was sort of the equivalent of the NISE Net but in a European fashion. And this was a series of exhibits and deliberative discussions that went on in science centers and museums across Europe during a two-year period and resulted in a paper of recommendations to the European community about what the public needs to know in order for there to be a clear path for development of nanotechnology for economic and industrial purposes. It hasn't gone quite that way in the US just because of the decentralized nature of US government… and NISE Net is sort of imitating that in its structure. So we're a very distributed kind of network. It's not really

> hierarchical; we're spreading out in more of a free-scale kind of fashion with nodes that are fluid. (Interviewee #3 2008)

In other words, the NISE Network is an initiative developed with broader political-economic considerations in mind, and "public understanding" and engagement efforts may be most helpfully analyzed in this context as well. The NISE Network is indicative of the shifts discussed above toward a post-Fordist, "post-industrial," supposedly knowledge-based political-economy, in which emphasis on technology and information have replaced emphasis on industry and manufacturing. According to David Rejeski, Director of the Project on Emerging Nanotechnologies (www.nanotechproject.org; accessed February 2012), "By 2014, nanotechnology is expected to account for over $1.4 trillion of global economic production" (Rejeski 2008: 3). He goes on to emphasize not only the potential benefits but the downsides of nanotechnology, particularly its public health risks, given that, "Animal studies have shown that nanoparticles can enter the bloodstream, cross the blood-brain barrier, and damage tissue and DNA" (Rejeski 2008: 3). While all of these issues are vital, it is also important to situate nanotechnology in the broader context of U.S. political-economy, per the interviewee's comments above. This context includes changing job structures, industries, and deindustrialization – trends that pose risks to livelihood and well-being at the social and class-levels, as well as the individual level.

New Media Ecologies: IMAX Theaters, Blockbuster Exhibits, Cyberspace & Place-Making

While the initiatives described above, in part, register shifts from Fordist to post-Fordist production, science museums have also been affected by changes in the realm of consumption, particularly cultural consumption and media ecologies. Indeed, these consumption changes are in many respects the flipside of shifts in production, away from industrial manufacturing and toward the service sector, including urban cultural industries. As Fantastia and Voss describe their approach to analyzing the situation of U.S. workers, "consumption and production [are considered] together as mutually constituting practices and as dual mechanisms of exploitation, rather than as distinct spheres of economic activity" (Fantasia and Voss 2004: xiv). In their analysis of the rise of post-Fordist "new economy" discourse, they note that, not only is the U.S. oriented toward individualism, but increasingly this individualism is defined by consumerism rather than production and work. "That is, the Worker (a social actor whose interests were once identifiable and recognizable in a range of institutional forms) has gradually 'disappeared' from the social imagination and has been replaced by the increasingly discernible figure of the Consumer" (Fantasia and Voss 2004: 27). The forms of new media described below, which have taken off at science museums since the 1980s, reflect the competitive urban entertainment marketplace and the urban cultural industries with which science museums must compete. Rather than being driven first and foremost by pedagogic objectives, science museums have deployed these media in order to compete for consumer dollars in the urban cultural landscape, and to grapple with the increasing pervasiveness of digital media. In so doing, they too approach individuals as consumers rather than workers – with the Franklin Institute, founded in the early 19th century as a mechanics' institute, the most dramatic example of this shift. Thus I turn to its transformations during this period at the end of this section.

IMAX Theaters & Science Museums

Though science museums, particularly the latest generation science centers, tended to be guided by a mantra of learning via "firsthand experience" and "hands-on" exhibits, one key development at many science centers in the 1980s and beyond was the addition of large-format IMAX or Omnimax movie theaters, which broadcast sounds and imagery from far and wide. As was the case for many science museums themselves, the large-format film technology for these theaters emerged from world's fairs. Specifically, after the 1967 Montreal world's fair, Canadian filmmaker Graeme Ferguson and several high-school friends, who were frustrated by the limitations of world's fair exhibits at the time, formed the Imax Systems Corporation in Toronto to develop a projector for large-screen theaters, rather than relying on multiple projectors for such a screen (Kirk 1981: 13). As such IMAX theaters developed, they featured unprecedented levels of surround-sound and visual immersion, raising anew the question of just what constitutes "firsthand experience," particularly in the context of complex contemporary media ecologies. Imax and Omnimax theaters were U.S. science museums' response to the broader media ecologies in which they – and their approaches to displaying "the natural world" – were situated. Opening first in San Diego in 1973, such theaters were added to science museums across the U.S. and beyond throughout the 1970s, 1980s and in later decades.

While various pedagogic rationales were articulated for the value of Imax theaters to science museums, first and foremost, the growing popularity of IMAX theaters at U.S. science museums was driven less by any new philosophy or program of science pedagogy than by the financial exigencies of many museums. As a 1987 *Wall Street Journal* article entitled "It's Show Time: Science Museums Open Big-Screen Theaters to Boost Attendance" reported:

> Science museums are increasingly turning down their lights and pulling in the crowds with such giant-screen theaters. They are part of the museums' new emphasis on marketing to broaden their appeal and to hedge against rising costs and government funding cuts. About 15 U.S. museums now have giant-screen theaters, and at least five more are planning to install them in the next few years. While some criticize the theaters as more entertaining than educational, the museums say they need such attractions to set themselves apart from other activities that siphon off potential museum-goers. (Fuchsberg 1987: 21)

IMAX theaters were, literally, the next big thing for science museums trying to meet visitors' expectations for novel, fun forms of cultural consumption. As the Boston Museum of Science's associate director, John W. Jacobson, explained in the 1987 article, "We're living in a crowded electronic village…. We've had to fight with the local movie houses and other diversions to get people to come." Meanwhile, according to Joel Bloom, president of the Franklin Institute, which was in the midst of raising $40 million for an expansion that would include a large-screen theater, "Museums have got to sell better to gain a larger share of the leisure dollar. We've changed our advertising strategy, and we've got a new jingle, too." While the large-screen theaters were expensive to build, costing $5 million to $12 million at the time, museums tended to fund them through private donations and fund-raising drives specifically oriented toward theater construction. Operating costs would be covered by ticket-sales as well as increased attendance revenue – or so the thinking ran at the time.

In practice, the outcomes for science museums of building Imax and Omnimax theaters were mixed. In some cases, such theaters were credited with helping museums improve their finances and attendance rates – while in others, theaters were only self-supporting, or even proved unviable over time. The theater at the downtown Detroit Science Center, for example, was no match for countervailing centrifugal forces of white flight and capital flight away from downtown and urban cultural life. High advertising costs in Los Angeles and New York, meanwhile, made it difficult for the California Museum of Science and the American Museum of Natural History to promote and therefore leverage their new theater investments as other museums had done. Another challenge was the relative paucity of films for Imax and Omnimax theaters, and the problem of continually supplying audiences with new films, as did other movie theaters. To this end, in 1985 the Boston Museum of Science initiated the Museum Film Network along with the Chicago MSI, the Detroit Science Center, the Science Museum of Virginia, San Diego's Reuben H. Fleet Space Theater and Science Center, and the National Museum of Natural Science in Taiwan, "to produce exciting science films for presentation in Imax and Omnimax theaters" (Boston Museum of Science 1987). While this network could not match Hollywood's output of novel films for other movie theaters, large-format theaters at science museums continued to provide uniquely encompassing viewing experiences to visitors. By the turn of the 21st century, however, science museums' majority share of all large-format theaters was shrinking. According to an August 2000 report on "Giant Screen Films and Lifelong Learning" (Koster 2000), non-profit museum-based theaters made up only 56% of all such theaters worldwide – whereas they had initially housed nearly all such theaters. Again, science museums struggled to differentiate themselves amidst dynamic contemporary media ecologies, while also articulating and documenting their unique educational value.

Blockbuster Exhibits & Science Museums

Another trend at U.S. science museums during these years and up through the present has been the emergence of so-called "blockbuster" exhibits – temporary, traveling exhibits that tend toward grandiosity in their themes and presentation, while echoing the discourse of the film industry to appeal to audiences. Blockbuster exhibits were another response by science museums to the broader media ecologies in which they were situated, particularly the challenge of competing with other cultural institutions and appealing to broad publics amidst an array of leisure options. Sometimes these exhibits were even organized around themes and characters from other forms of mass media, such as movies and TV shows. For example, in 1992 the Oregon Museum of Science and Industry (OMSI) opened the exhibit "Star Trek: Federation Science," which went on to tour other science museums throughout the U.S. The exhibit, coinciding with the TV show's 25th anniversary and produced with Paramount's permission, was OMSI's largest to date, "with 40 modular displays covering 6,000 square feet" (Arnold 1991: 13). Speaking to *Star Trek*'s popularity, Geoffrey Arnold, OMSI public relations representative, noted that, "The image of tomorrow portrayed in [the *Star Trek* TV series] appeals strongly to all ages and to every segment of society. A poll conducted by the National Research Group, Inc., indicates that 53 percent of the American public consider themselves to be *Star Trek* fans; the name *Star Trek* is recognized by a remarkable 99 percent among all demographic groups" (Arnold 1991: 13). Such statistics indicate the extent to which many science museums had become savvy about market research and demographics in planning their exhibits, particularly blockbuster exhibits.

Yet, like IMAX films, while such blockbuster exhibits might increase attendance and revenue at science museums, they also raised questions about just what constitutes "science education" – and what is beyond its bounds. Were blockbuster exhibits a creative and dynamic means of engaging publics with science – "rational amusement" as earlier commentators might have put it – or mere entertainment? Again, the contemporary cultural cartography of science was at stake, with attempts by science museums to both define themselves as part of the realm of credible science and compete for urban entertainment dollars in order to remain solvent. The example of the *Star Trek* exhibit is especially fascinating in this regard because it drew on popular science fiction, even as promoters emphasized its factual, science educational value. As Arnold described its pedagogic content:

> Throughout the exhibition, visitors will learn the way scientists do – by experimentation. The main focus is on scientific principles that are expected to challenge scientists in the future, including particle physics, practical astronomy, and living and working in space. The principles behind propulsion systems, medical science, and life support will be intertwined with basic research areas such as the structure of the galaxy, orbits, relativity, and planetology…An exhibit called Gravity Billiards uses gravity wells to represent stars and planets to show visitors how spacecraft (marbles) would travel through the solar systems, represented by an octagonal table covered with a rubber sheet and plastic mold. Another exhibit will allow visitors to merge their features with those of an alien by sitting in front of a half-silvered mirror. (Arnold 1991: 13)

Thus the exhibit seamlessly mixed "science fiction" and "science fact," while emphasizing its value as a vehicle of science education, not merely entertainment.

Another institution against which science centers sometimes had to define a boundary was the amusement park or theme park – given the similarities between blockbuster exhibits and theme park attractions. Just as Kaempffert and other earlier museum representatives had sought to differentiate science museums from amusement parks, contemporary voices often worked to perform similar boundary-work – articulating the ways in which blockbuster exhibits were not just another amusing gimmick, of the sort that might be found at supposedly less respectable places, such as Sea World or Disneyland. For example, in a 1997 article in *The Informal Learning Review* entitled "Are Science Centers and Theme Parks Merging?" Alan J. Friedman, Executive Director of the New York Hall of Science, spoke to the increasing problem of differentiating science museums from commercial theme parks:

> Science-technology centers like the New York Hall of Science have enjoyed a near monopoly on providing the public with hands-on learning experiences. In the 1990's, however, commercial playgrounds are calling themselves 'Discovery Zones,' and theme parks are offering curriculum guides. 'Edutainment' has become a common descriptor of computer games, simulations, and CD-ROMs. The pitch of the edutainment industry is similar to that of any science-technology center: 'Come and have a great time and learn a little something too.' (Friedman 1997: 1)

Friedman goes on to argue that there are fundamental differences between science centers and "our edutainment competitors" (Friedman 1997: 1). He emphasizes that science centers put education before entertainment, are not driven to maximize profits, and do not manipulate visitors, as do theme parks, but instead allow visitors to manipulate exhibits. These points perform the boundary-work of differentiating science museums from theme parks and other commercial establishments – including those devoted to displaying "the natural world" in a framework of edutainment, such as Sea World. They frame science museums as part of the field of ISE, not entertainment.

Yet how different, really, is the sort of information presented at Sea World from the information and ethos of blockbuster exhibits at science museums – or science museums in general? Another perspective occasionally encountered among science museum professionals is that science museums and theme parks can learn from each other. For example, the ASTC's 1990 annual meeting at the Orlando Science Center was entitled "Making Science Memorable: The Reciprocal Roles of Science Centers and Entertainment Parks." The conference's opening keynote began, "In the past, museums existed primarily to preserve and protect the material and technological wealth of the industrial society…But, as we transform to the information age many museums are themselves becoming fossils and theme parks are answering the need for information for the masses," according to George MacDonald, director of the Canadian Museum of Civilization, as he spoke in front of a jungle waterfall on a stage at Universal Studios. He went on to "challenge…science centers to bend their concept of what a theme park is, and to consider ways that museums might profit from theme parks' experience" (ASTC 1991: 1). The keynote argued that rather than criticizing theme parks and conveying jealousy-driven disdain, science centers should try to understand the reasons for theme parks popularity. It also noted that the Orlando area had become a bigger attraction to visitors than "traditional pilgrimage centers such as Rome, Jerusalem, and Mecca" (ASTC 1991: 4). The keynote embraced theme parks and their potential synergy with science museums, rather than perpetuating the more typical boundary-work of the field. It was followed, however, by voices critical of such a rapprochement, such as Ted Ansbacher, who implored, "Let us not be seduced by the easy route to large attendance, or led astray by the notion that to compete with entertainment-leisure activities we must emulate them" (ASTC 1991: 4). Thus while the dominant trend of the science museum field has been to distance museums from theme parks, framing the latter as unreliable, this boundary has remained ambiguous and fraught – and practical considerations have pushed museums in both directions: toward both distancing and embracing. The cultural cartographies of science in which science museums are embedded are similarly fraught.

Science Museums, Cyberspace & Place-Making

Beginning especially in the 1990s, another media development taken up by science museums and affecting their broader media ecologies was the growth of cyberspace and digital environments. Science museums' engagement with the Internet unfolded in several stages, intertwined with the development of the Web itself – beginning with the development of museum Web sites in the 1990s, to museums' use of Web 2.0 social media technologies and virtual immersive environments in the 21st century. I consider these key junctures below, including their significance for science museums and place-making in contemporary cities and suburbs, as part of larger national landscaping projects.

In a 2001 article entitled "Nodes and Connections: Science Museums in the Networked Age," Rob Semper of the Exploratorium reflected on the changes brought about by the Internet over the previous decade and science museums' use of Web sites. He began by emphasizing their synergies:

> The World Wide Web and museums were made for each other…The similarities among museums and the Web are many. Both are user-driven: In the museum, visitors browse with their feet, choosing which exhibits to explore; on the Web, people surf with a browser and choose where to go on a page. Both support two-way dialogue and community: In the museum, visitors interact with friends, family, and strangers while exploring exhibits; online, users interact with friends, family, and strangers while using common materials. Both engage the visitor through text and image and sound. Relevant

content is critical to both. And both, at their best, become a personal, individual medium, almost infinitely configurable. (Semper 2001: 3)

Semper highlights the ways in which the Web and museums resonated and shared formal characteristics as media – including the ways in which science museums might create virtual museums through their Web sites. In the case of the Exploratorium, which launched its Web site in 1993 – when there were still only 600 Web sites worldwide – this was the goal from the beginning, according to Semper: "[O]ur goal was to create an authentic virtual museum, one rich with things to see and do. Online exhibits, multimedia exhibitions, and real-time experiences would provide interest to our Web site visitors in the same way that exhibits, exhibitions and live experiences provide interest to museum visitors" (Semper 2001: 3-4). At the same time, he emphasized that Web site developers regarded the Exploratorium's site as an extension of the museum, "anchored in a physical exhibit place," rather than floating in cyberspace.

On the other hand, Semper also reflects on the potential disconnects and competitive dynamics between museums and the Web, based especially on museums' physicality, in contrast to the Web's virtuality. As he puts it, "[T]his technology also has the potential to compete with us. Web browsing has become a major leisure-time activity… By using the Internet, the mass media have become more interactive, more targeted, and more pervasive" (Semper 2001: 4). In other words, while science museums had in the past emphasized their greater "interactivity," compared with mass media such as TV and film, the growth of Internet-mediated programming had begun to break down such distinctions. In addition, Semper continues, "Historically, the strength of science centers has come from unique placeness and identity." Yet the networked character of the Web abides by an entirely different logic, whereby "One of the wonders of the Web is the way it facilitates connections between people in different places, different roles, and different times" (Semper 2001: 4-5). Ultimately, Semper situates both the Internet and museums in the context of contemporary "distributed learning environments," which have the potential to break down older, "artificial" boundaries. Semper then speculates about the possibilities for networking specific physical places with unique identities and communities, such as the Exploratorium, along with far-flung places and people – all, ideally, learning from and with one another. Here Semper picks up on the discourse of the supposedly post-industrial, knowledge-based, "learning society," echoed by others throughout the science museum and STEM communities. Yet his attention to physical places in tension with digital "places" and networks raises interesting questions and possibilities.

As newer, more immersive digital technologies are introduced at science museums, discussion of the relationship between physical places and cyberspace may fall by the wayside, replaced by greater attention to the "participatory" possibilities of Web 2.0 social media technologies and Web 3.0 virtual immersive environments, independent of physical geographies. For example, a 2007 ASTC newsletter with the theme "Immersed in Science: Learning in Today's Digital Environments," includes multiple articles on virtual reality and on topics such as the relation between museums and their Second Life incarnations, or the relation between Web 2.0 and Web 3.0. Sometimes these discussions turn to engagement with physical places; for example, an article on the use of Second Life at the Exploratorium emphasizes the way it can be used to virtually explore inaccessible places and events, such as viewing a total eclipse of the sun on the other side of the world (Doherty and Rothfarb 2007). Yet, the focus on virtual realities and the latest frontiers of digital immersion may also move discussion of cyberspace and "distributed learning environments" further from everyday physical places and people's embodied lives in those places. In the process, participation in the form of physical, communal place-making in people's everyday lives – including via science and technology – may be overlooked, or undermined.

The Franklin Institute: Championing the Role of the Individual-As-Consumer

As mentioned previously, in order to analyze late 20th century science museums in the broader field of urban entertainment and new media ecologies, it is helpful to recognize the mutual constitution of production and consumption relations in the accelerating shift toward a post-Fordist political economy in the U.S., during the 1980s and beyond (Fantasia and Voss 2004). This shift has included not only heightened discourses of individualism, but individualism defined by consumerism rather than production and work. Given the Franklin Institute's origins as a place of technical and vocational education for workers, how has it been transformed in more recent years? As mentioned above, the Franklin continued its involvement in research even after its reinvention as an industrial science museum in 1934, including through its Bartol Research Foundation. Throughout World War II, the institute's research facilities conducted optical and electrical research to aid the war effort, its labs growing from 9,000 to 43,000 square feet. The Franklin participated in the mid-20th century trend toward emphasizing "basic science" as a route to applied science, and managed to lure top university faculty to leadership positions – establishing itself as a player in the broader scientific field and the production of scientific knowledge. In 1951, it opened a new applied research center, the National Asphalt Research Center, while the Bartol Research Foundation opened a nuclear accelerator. The institute's research won contracts from both government and the private sector. By the 1970s, it could be described as "one of the ten largest not-for-profit, non-university affiliated contract research laboratories in the United States" (Franklin Institute manuscript "Unplanned Legacy," as quoted in Conn 2010: 168), with an annual budget of $20 million and a staff of 600. By 1980, the institute announced a new Franklin Institute Policy Analysis Center "to study the impact of private and public policies involving science and technology on public health and well-being, and to communicate its findings to the public and to appropriate decision-making bodies" (as quoted in Conn 2010: 168). At that time, the institute's research activities reportedly surpassed any of its other activities, including the museum.

In 1983, however, the Franklin Institute's annual report announced that research activities had been reevaluated, and the next year the Research Center closed. A couple years later, the institute divested completely from the Bartol Research Foundation, which became part of the University of Delaware. At the same time, by 1989, the Franklin Institute's board of trustees declared its intention to focus entirely on the science museum and to expand it, to become not only a regional but a national attraction. The museum would aspire to "move from a regional to a national resource, from one that teaches the basics of science to one that champions the role of the individual in determining how technology may shape the future, from one that while considered an aggressive marketer among non-profits must now compete with major commercial attractions for its audience" (as quoted in Conn 2010: 168). In other words, the Franklin Institute, too, shifted its priorities and practices over these years, positioning itself and its visitors as part of burgeoning urban cultural industries and landscapes of consumption, rather than production. Today, the Franklin features IMAX films, 3-D films, touring blockbuster exhibits, and a range of digital interactive exhibits, including a temporary video game design lab. Table 2 below provides an overview of the transition from early 20th century industrial science museums' exhibitionary conventions to late 20th century science center conventions, in relation to the 19th century discourse of "rational amusement"; while this phrase is now archaic, contemporary debates over “edutainment,” regarding the line between education and “mere entertainment,” perpetuate concerns and distinctions from this earlier discourse.

Reconfiguring "Rational Amusement": From Early 20th Century Industrial Science Museums to Late 20th Century Science Center Museums …

	Rational Amusement Pedagogic Elements: Practices and Discourses	***Core Exhibitionary Conventions of Rational Amusement***	***Direct Challenges to Exhibitionary Conventions of Rational Amusement***	***Liminal Exhibitionary Practices: Possible Challenges to Exhibitionary Conventions of Rational Amusement***
Early 20th Century Industrial Science Museums	***Practice:*** Emphasis on "real things," rather than texts – especially mechanized, push-button operated exhibits	Initial emphasis on evolutionary taxonomies; later, more emphasis on immersive environments & spectacular exhibits	No equivalent of *lusus naturae* and no clear challenges to rational amusement; habitat dioramas totally accepted	The spectacles and attractions of world's fairs, including their dime museum & amusement park-like midways
Early 20th Century Industrial Science Museums	***Discourse:*** Populist discourse of "hands-on" and experiential learning; but less emphasis on object lessons as exemplifying the "natural order"	The U.S. as a great powerhouse of Yankee ingenuity, technological progress, and industrial civilization; the natural world as natural resources	In urban-industrial world of human-created objects, nothing clearly "outside" the natural order (as *lusus naturae* thought to be); perhaps only sci-fi entities	Industrial museums still aspired to the cultural legitimacy of museums, with higher status than amusement parks; "technological Coney Islands" as new "others" – but boundaries vaguer
Late 20th Century Science Center Museums	***Practice:*** Emphasis not only on physical objects but on digital "interactives" & multisensory learning	Emphasis on educational objectives, whatever the exhibit; no clear practices to signify this status	Again, no equivalent of *lusus naturae* and no clear challenges to rational amusement	Amusement park-like attractions, including IMAX films and blockbuster exhibits
Late 20th Century Science Center Museums	***Discourse:*** Continued populist discourse of "hands-on" and experiential learning; critics might dismiss as mere "edutainment"	The U.S. national-industrial narrative has been replaced by emphasis on "basic science" and, later, technology and engineering, to compete globally	Again, in urban-industrial world of human-created objects, nothing clearly "outside" the natural order	Non-profit science centers still aspire to the cultural legitimacy of museums, with higher status and educational credibility than amusement parks

Chapter 5: Table 2: Reconfigured Rational Amusement Exhibitionary Practices & Discourses

Natural History Museums Revisited: The Heterogeneity of the Late 20th Century Science Museum Field & Divisions of Labor in Displaying "The Natural World"

This chapter began with a discussion of the Boston Society of Natural History, and the reinvention of its New England Museum of Natural History as the Boston Museum of Science. This reinvention included the reframing of "science," to encompass not only natural history and "first nature," but applied science and the "second nature" of industry, marked by technological transformation of the world: the human-built world (Hughes 2004). In this way, some natural history museums incorporated the legacies of the early 20th century industrial museum movement, laying the groundwork for their participation in the postwar science center movement, as it took off and further transformed the field. In particular, they did so by deemphasizing collections and artifacts, as well as history. This pathway from amateur scientific society and/or natural history museum to science-technology center, more or less influenced by industrial science museums along the way, was one of the main ways that 19th-century and early 20th-century natural history museums transformed in the postwar era. Besides the Boston case, other examples of natural history museums following similar routes are: the Denver Museum of Nature & Science (founded as the Colorado Museum of Natural History in 1900); the Maryland Science Center (opened in Baltimore in 1976 by the Maryland Academy of Sciences, established as an amateur scientific society in 1797); and the New England Science Center (opened in Worchester, MA in 1971, by the Worchester Natural History Society, established in 1825).

Other institutions, however, maintained their orientation as natural history museums, even while incorporating certain exhibitionary conventions of science centers. These institutions tended to be the largest natural history museums with the grandest collections and habitat dioramas, as well as those in larger cities. The foremost examples are the American Museum of Natural History in New York, the Field Museum in Chicago, and the Smithsonian's National Museum of Natural History, as well as somewhat smaller institutions such as the California Academy of Sciences. Natural history museums with larger collections and dioramas could more easily remain impressive and stand out for visitors in broader media ecologies. They are also likely to have larger endowments and greater resources for bringing in new attractions and traveling exhibits, including blockbuster exhibits, and maintaining active research programs, in articulation with their collections, thereby supporting their continuance as natural history museums. Meanwhile larger urban areas were more likely to support multiple science museums and venues for displaying "the natural world," including both natural history museums and science centers, or science and industry museums. Such is the case in not only New York and Chicago, but in the San Francisco Bay Area, where the California Academy of Sciences (CAS) has continued to reinvent itself as a natural history museum (Wels 2008), even as the Exploratorium came on the scene in 1969, and the Tech Museum in San Jose opened with a more "applied science" and technological orientation in the 1990s.

At the same time, while many natural history museums have continued as natural history museums, they have joined in the process of reinventing their exhibitionary conventions, often drawing on "hands-on" approaches from science centers. For example, at the California Academy of Sciences, visitors can not only look at an electric eel in the aquarium portion of the museum, but also touch a panel designed to deliver a mild electric shock, to simulate the effect of encountering an electric eel in the world beyond the museum. Touch tanks that enable visitors to pick up or otherwise handle creatures such as starfish are another example of "hands-on" science deployed in aquarium and natural history museum settings. The CAS has thus developed its own approach to "hands-on" science in its exhibits, in a natural history register.

On the other hand, some natural history museum staff emphasize that conventional natural history displays, particularly habitat dioramas – an exhibitionary innovation drawn on by industrial science museums – foster forms of interactivity that are not dependent on hands-on manipulation or digital devices. As an associate of the Smithsonian's National Museum of Natural History put it in an interview:

> As much as we want to have hands-on interactivity, and we are building more and more in, I think that the strength of a lot of natural history exhibits is that experiential piece…and actually I think even directive questioning can be interactive, if you have people look at something and then look again, or just looking at an object in a really provocative way or with good questions… So I don't think it always has to be a hands-on manipulative for it to be engaging. (Interviewee #4 2008)

Here, the emphasis on the "interactivity" of exhibits that are not generally viewed as such could be taken as evidence of the power of this frame of visitor engagement – and the influence of science centers – in the science museum field. At the same time, the interviewee raises important questions about the meanings of "interactivity" and varieties of engagement, which are often taken for granted at science centers as long as exhibits feature opportunities for "hands-on" manipulation by visitors. Yet interactivity and engagement may also include the intellectual, emotional, and imaginative realms, which the quotation suggests are touched by natural history exhibits, even if these exhibits are not touched by visitors. Science center professionals sometimes speak about these complexities of "interactivity" as well, when they refer not only to hands-on interactivity, but "minds-on" and "hearts-on" interactivity (Russell 1997). These arguments suggest that the boundary-work of earlier industrial museums and science-technology centers, to portray natural history museums as stultifying rather than "interactive," was based on a particular set of assumptions about interactivity and engagement, emphasizing hands-on manipulation.

Beyond exhibitionary conventions, for those natural history museums that stayed the course, many continued or even extended their research programs over the years. Active research agendas at natural history museums mean the continued relevance and dynamism of collections, not only in exhibitions, but also behind the scenes, in museums' taxonomic storerooms and laboratories. Over the years, as threats to biodiversity increased and species extinction accelerated, natural history museums' repositories of specimens, as well as their contemporary research, gained new significance. In addition, climate change and its effects on ecosystems around the world added new urgency to natural history museums' research agendas – as articulated at the CAS' new permanent exhibit on climate change, situated alongside a hall of early 20th century habitat dioramas. In this context of ecological change and destruction, a book about the history of expeditions and research at the AMNH, *American Museum of Natural History: 125 Years of Expedition and Discovery*, declares:

> Natural history museums…possess the knowledge to maintain a biodiversity triage desk, essential for sound and economically realistic conservation priorities. The role is implicit in the work they have been doing for more than a century. (Rexer and Klein 1995: 226)

Natural history museums today, oriented toward raising awareness about biodiversity, habitat loss, and ecological harm, are in many ways building on the legacies of 19th century "salvage anthropologists" and naturalists. At the same time, leading natural history museums are adding new infrastructures to support their research agendas. The AMNH opened a Molecular

Systematics Laboratory in 1990, and also the Richard Gilder Graduate School in 2006, which supports a Ph.D. program in Comparative Biology. More specifically, the mission of the latter is "to train the next generation of biologists through an approach that focuses on the history and interactions among species, and that takes advantage of the American Museum of Natural History's unique and unparalleled resources, including its world-renowned collections" (http://rggs.amnh.org/pages/school_overview/mission; accessed February 2012). The AMNH is fostering, with new tools, the sort of comparative, historical and ecologically oriented life sciences research that natural history museums and their systematists, drawing on fieldwork, have always emphasized. This approach to life sciences research contrasts with the reductionism of laboratory-based molecular biology, perceived as the cutting-edge of life sciences research throughout much of the 20th century and into the 21st century. Science center museums have also featured exhibits on climate change and biodiversity over the years – particularly during the International Action on Global Warming (IGLO) initiative of the ASTC, between 2007 and 2009 – though they have not advanced alternative paradigms of life sciences research, perhaps partly because they lack natural history museums' collections as bases for such research.

By the end of the 20th century, the science museum field was very heterogeneous – composed of natural history museums, industrial science museums, science-technology centers, and, arguably, kindred natural history institutions with living collections, such as zoos, aquariums, and botanical gardens. One consequence for the science museum field as a whole is that a division of labor has tended to develop across major science museums and science museum types, such that "the natural world" of natural history may be displayed most grandly in institutions kept separate from "the natural world" of science centers and industrial (or technology) museums. This fragmentation obscures perception and analysis of relationships between the "first nature" of natural history museums and applied science, or "second nature" – including the social relations through which "first nature" and "second nature" are constituted. Even natural history museum exhibits that focus on the consequences of human activities on ecosystems – such as exhibits on climate change or species extinctions – do not veer far into analyzing sociological and organizational dimensions of resource use, including the inequalities within and among societies. Instead, "solutions" tend to be framed in individual terms, without situating the generic "individual" in broader social contexts, including in terms of nation-state, race, class, and gender. Issues of environmental justice are thereby often neglected, even when sustainability is discussed. Alternatively, reinvented natural history museums may deploy "smorgasbord" approaches to exhibition – but often, not in a way that provides visitors with the analytic resources to think critically about the relationships between "the natural world" of natural history, on the one hand, and technology and industry, on the other. Meanwhile, the cultural problem of "civilizing the machine in the garden" – the attempt to balance industrial exploitation and conservation – remains, particularly in the context of deindustrialization and the unraveling of the urban-industrial national landscaping project. Table 3 below provides an overview of these broader national landscaping projects, to put in historical geographic context science museums' displays of "the natural world" and debates about "rational amusement." I reflect further on these themes and threads running through the dissertation in Chapter 6.

U.S. Science Museum Eras & National Landscaping Projects ("External Spatial Orders")

Science Museum Type	***National Landscaping Project***	***Key Actors & Institutions***	***Geographical Transitions At Stake, on Multiple Scales***
19th Century Natural History Museums	Territorial Surveying & Incorporation	National Exploring Expeditions & Surveys	"Wilderness" landscapes converted into natural resources and farmland, laying the groundwork for urban-industrial development
Early 20th Century Industrial Science Museums	Urban-industrial development, fueled by exploitation of natural resources (e.g. mining)	Industrial corporations, in context of nation-state policies oriented toward national industrial and infrastructural development (including, the New Deal)	Accelerating shift toward urban-industrial development, accompanied by territorial consolidation via transportation and communications infrastructures
Late 20th Century Science Centers	Deindustrialization of former urban-industrial strongholds (e.g. the Northeast and Midwest)	Industrial corporations, in the context of nation-state policies oriented toward deregulation and trade liberalization, facilitating capital flight	Accelerating suburbanization, often accompanied by urban deindustrialization and capital flight; dawning of "post-Fordist" era (termed "post-industrial" era by some)

Table 3: "Civilizing the Machine in the Garden" in an Era of Industrial Automation & Capital Flight?

Chapter 6: Concluding Reflections on "Public Understanding of Science" & Everyday Life

"The future is already here – it's just not very evenly distributed."

– William Gibson, science fiction writer

"Multiply entry and exit points."

– Jean-Pierre Gorin, filmmaker

This dissertation has examined the U.S. science museum field over time in order to examine institutional emergence and transformation pertaining to science boundary-work. It has investigated the emergence of the U.S. science museum field via 19^{th} century natural history museums and world's fairs, and the 20^{th} century transformation of the field by industrial science museums and science centers. Its theoretical contribution is to underscore the significance of material culture and its spatial dimensions to analyzing the emergence and transformation of institutions, including patterns of boundary-work between publics and science. Moreover, this dissertation argues that theories of science boundary-work too often neglect conjunctures between "cultural cartographies of science" and physical space, including political-economic geographies. In order to adequately analyze boundary-work at science museums, this dissertation has argued that it is fruitful to examine science museums as relational spaces with "frontstages" and "backstages," in conjunction with broader geographies and external spatial orders.

It has found an overarching trend toward greater hands-on "interactivity" in science museum exhibits over time; a move toward smorgasbord spatial layouts (rather than taxonomic organization); an embrace of popular culture, particularly to compete in the urban entertainment marketplace in the context of new media ecologies; a shift toward younger audiences, particularly at science centers; and declining emphasis on collections, historic artifacts and research at many science museums, following the science center movement – with natural history museums a notable exception. It has also found that *lusus naturae*, a concept crucial to framing "rational amusement" and the natural world at the earliest U.S. science museums, fell out of discussion in the 20^{th} century science museum field, as professionalized science and "second nature" expanded. Finally, this dissertation found that while the 20^{th} century science museum field was transformed by two museum movements – the industrial museums movement and the science center movement – the latter was far more influential than the former, in terms of institution-building and proliferation. It has argued that science centers proliferated more rapidly than industrial science museums due not only to new constituencies mobilized on their behalf, but also due to their de-emphasis on collections, particularly of rare and historical artifacts. These changes also facilitated new exhibitionary conventions, underscoring the importance of material culture to institutional emergence and proliferation, on multiple levels. These institutional trends, in turn, shaped exhibitionary trends and patterns of boundary-work over time.

One consequence of science centers' shift away from collections is that historical narratives of science, technology and industrialization – and deindustrialization – have tended to fall by the wayside. At the same time, some museums have shifted to an emphasis on future-oriented "technological literacy" and the importance of STEM education in the context of global economic competition. Moreover, ironically, in the late 20^{th} century, many science centers were either built partly to help revitalize deindustrialized urban areas or found themselves affected by such changing urban-industrial landscapes. On this note, this dissertation argues that science museums function as boundary objects among diverse communities of practice (scientists, industrialists, the state, educators, civic leaders, cultural philanthropists), enabling them to work cooperatively without consensus to build a culture of STEM education. It argues that the resulting public culture of science is fun, cool, "interactive," multicultural and environmentally concerned without engaging the deeper conflicts and disparate interests of various actors, especially industrial corporations.

Below I discuss the relevance of these findings contemporary discussions of STEM (science, technology, engineering, mathematics) policy, including education policy and approaches to "public engagement" and participation. I discuss how contemporary U.S. science museums contribute to the public culture of STEM, and how they and other actors might build – or are building – alternative public cultures of STEM. In particular, I examine the recent "maker movement" and its intersections with science museums, in the context of broader historical geographies. Here I focus on processes of place-making, at multiple levels and scales, in intersection with people's everyday lives and "local knowledge." I emphasize the significance of so-called "street science," mobilized in the context of movements for equity in communities' access to nature, or environmental justice, as crucial to the on-going cultural problem of "civilizing the machine in the garden."

U.S. Science Museums, the "DIY" Maker Movement & Framing STEM Education

While the science center movement of the 1960s and 1970s had in many ways become institutionalized and bureaucratized in subsequent decades, in 2006 a new movement arrived: "the maker movement," heralded by the first Maker Faire that year in San Mateo, California. The Maker Faire, which bills itself as an event to "celebrate arts, crafts, engineering, science projects and the Do-It-Yourself (DIY) mindset," was incubated and instigated by the Bay Area's technology community. More specifically, it was a spin-off of *Make* magazine, launched in 2005 with the subtitle "technology on your time," as part of O'Reilly Media, which aims at "spreading the knowledge of innovators." Exhibitors at past Maker Faires include the Exploratorium, alongside a diverse array of individuals and organizations – from corporations like Microsoft to worker-owned cooperative letterpress printers. Gradually, the movement spread to other cities, regions, and countries, with Maker Faires launched in Austin, Detroit, New York, and beyond. Its emphasis on hands-on tinkering, invention and technology caught the attention not only of the Exploratorium, but also of the broader contemporary science museum field.

In September 2010, the New York Hall of Science (NYSCI) hosted a two-day, NSF-funded workshop for science museum and ISE professionals, as well as those involved with the burgeoning "maker movement." With the theme "Innovation, Education, and the Maker Movement," the intent was to investigate how the maker movement "can help stimulate innovation in formal and informal education" (2010: 2). A report on the proceedings cites the reflections of Thomas Kalil, deputy director of the White House's Office of Science and Technology Policy, that the Maker Movement "begins with the Makers themselves — who find making, tinkering, inventing, problem-solving, discovering and sharing intrinsically rewarding" (2010: 1). In addition, the report "[r]ecogniz[es] that the Maker movement embodies aspects of science, technology, engineering, and mathematics (STEM) learning that are the hallmarks of effective education – deep engagement with content, critical thinking, problem solving, collaboration, learning to learn, and more…" (2010: 2) and asks, "How can the creativity and ingenuity that is core to the Maker/DIY movement inform and improve learning, particularly in STEM fields, in K-12 and career technical education?" In other words, the maker movement quickly received attention and praise from the ISE field and federal science and technology policy-makers. Maker Faires were regarded as innovative events from which older science museums and exhibit developers could learn.

In some ways, this new synergy echoes earlier catalytic ties between world's fairs and science museums. In 2010, for example, the NYSCI hosted the World Maker Faire, named in recognition both of the diversity of participants as well as the NYSCI's founding during the 1964-1965 world's fair. What was different, however, was the shift away from industrial exhibits and nation-states as the key frames for science and technology. Instead, these frames were replaced with an emphasis on DIY making, broadly construed. Indeed, as the report on the 2010 workshop describes, "Economically, a democratization of production is happening and we are seeing the beginnings of a powerful and distributed Maker innovation ecosystem. New products and services allow individuals to Design It Yourself, Make It Yourself, and Sell It Yourself" (2010: 5). The report cites technologies such as 3-D printers and computer-aided design (CAD) tools as examples of innovations that are supposedly enabling "a democratization of production," or putting a DIY ethic into practice. It mentions entrepreneurs such as Andrew Archer, the 22-year-old founder of Detroit-based Robotics Redefined, who builds customized robots to move inventory on the factory floors of auto companies, arguing that such makers "suggest a road map for a bottom-up renaissance of American manufacturing" (2010: 5). The paradoxical meanings of the DIY movement are exemplified by this statement, which frames an entrepreneur of robotics technologies designed to replace workers in auto manufacturing factories as part of the vanguard of a grassroots, DIY revival of American manufacturing. This ironic juxtaposition, among others, strongly suggests a disconnect between the framing of STEM initiatives in the maker movement, science museum field and broader ISE community, on the one hand, and broader political-economic and ecological issues of "making" – and unmaking – on the other.

The Elephant in the Landscape:
Capital Flight, Deindustrialization & the Detroit Science Center

Perhaps the supreme instance of the limitations of this contemporary framing of science and technology, including "hands-on" public engagement in STEM, by the maker movement and contemporary science museums, is illustrated by the experience of Detroit and its recently defunct Detroit Science Center. Founded in 1970, relocated and expanded in 1978, and reopened again in 2001, the Detroit Science Center officially closed in 2012, its former Web site even taken off-line (http://www.sciencedetroit.org/; access attempted March 2012). It was one of the 10 largest science museums in the country, according to Wikipedia, with "Michigan's only Chrysler IMAX Dome Theatre; the Dassault Systèmes Planetarium; the DTE Energy Sparks Theater; the Chrysler Science Stage; an 8,700-square-foot (810 m^2) Science Hall for traveling exhibits; hands-on exhibit galleries focusing on space, life and physical science; the United States Steel Fun Factory; an exhibit gallery just for pint-size scientists; and a Special Events Lobby" (Wikipedia, accessed March 2012). Yet in September 2011, reportedly due to the financial strain of its 2001 grand re-opening coupled with the recession, it closed to the public abruptly, at least to external appearances. On January 12, 2012, Crain's Detroit Business reported that the museum had laid-off its 5 last employees, with trustees citing a lack of funds and an inability to raise the necessary additional funds. While the trustees still hope to reopen the Detroit Science Center in the future, perhaps with the help of federal funds and a new business model, its current failure in the heart of a city that once was an industrial powerhouse is notable. It embodies the disconnect between urban consumer culture industries, in which science museums are now situated, and broad-based industrial production, which defined U.S. narratives of "applied science" in the early 20th century at industrial science museums.

"Maker Faire Detroit," which took place in 2010 and 2011, was actually located in Dearborn, MI, at the Henry Ford Museum. Though Dearborn is part of the Detroit metropolitan area, it is effectively a suburb of Detroit, with a majority white population (86.7% according to the 2010 U.S. census) and only 4% African Americans. In other words, it is a place removed from the immediate repercussions of capital flight, deindustrialization and white flight from inner-city Detroit that have shaped the city's current social and economic landscapes – the context for the Detroit Science Center's financial woes. This dissertation argues that these economic and historical geographies – including distinctions that some might see as minor, as between Dearborn and Detroit – are crucial to analyzing the social contexts of the maker movement and science museums, and their framings of public engagement with science and technology.

Maker Faires offer visitors fascinating opportunities, for example, to hear the creator of the pilot for the TV series "MacGyver" talk about how his father, a former WWII medic, had inspired the MacGyver character, and how he had consulted with Pentagon officials on this basis; to visit the Disney Imagineers exhibit and learn about the history of "imagineering"; or to check out various DIY artists' installations involving musically activated light displays to explore synaesthesia. However, as cool, fun and inspiring as Maker Faires may be, they do not raise larger questions around the forces and actors that direct research agendas in science and technology, or decide on commercialization strategies and trajectories, in the Bay Area and beyond. They do not distinguish among disparate "makers" – from corporations to individual artists to worker-owned cooperatives – who are oriented toward DIY on very different terms. Ultimately, they do not raise larger questions around the forces and actors that decide who benefits from scientific and technological breakthroughs, as well as longstanding innovations. Nor do science museums tend to raise these questions, regardless of their interactive exhibitionary approaches and participatory strategies.

Perhaps this is not the objective of science museums or Maker Faires. They are certainly not responsible for these broader social, economic and ecological problems, nor can they ultimately solve them. Yet they are responsible for framing science, technology and public engagement in particular ways, and this dissertation argues that these frames could be more critical. Science museums, Maker Faires and kindred entities could ask deeper questions about the meanings of "public participation," and the relationships among science, technology, ecology and democracy. These questions need not be mutually exclusive with the cool, fun and inspiring – particularly as they foster deeper participatory democracy, greater social justice, and more widely shared creativity. Below I outline some key touchstones to those ends.

"Street Science," Local Knowledge & Community Expertise:
Science for Environmental Health & Justice

While many ISE professionals have moved away from a deficit model for framing public science literacy and public understanding of science, overall the ISE and STEM education fields have not explicitly embraced alternative positive definitions of public science literacy, such as notions of community expertise and "street science" articulated by activists and scholars in environmental justice movements. These notions start from recognition of environmental inequities, particularly their implications for public health, and engage the dynamics of expertise – including its relations to local knowledge and everyday life – based on this entry point. For example, this approach to expertise characterizes Jason Corburn's book *Street Science: Community Knowledge and Environmental Health Justice* (Corburn 2005), which lays out a comparison of "local knowledge" and "professional knowledge," including both research and regulatory science in the latter category. Corburn distinguishes local knowledge and professional knowledge based on the following questions pertaining to knowledge production: 1) Who holds it? (e.g. members of community vs. members of profession); 2) How is it acquired? (e.g. experience vs. experimental/epidemiologic studies); 3) What makes evidence credible? (e.g. lived experience vs. statistical significance); 4) Forums where it is tested? (e.g. public narratives vs. peer review); and 5) Action orientation? (e.g. consensus over causes unnecessary for action vs. scientific consensus over causes desired for action) (Corburn 2005: 51). He acknowledges crossovers particularly in the latter category (action orientation), and emphasizes the contributions of both types of knowledge as guides to policy and decision-making. As he explains:

> The book offers a new framework for environmental health justice that joins local insights with professional techniques, a combination that I call 'street science.' This book shows that 'street science' does not devalue science, but rather re-values forms of knowledge that professional science has excluded and democratizes the inquiry and decision-making processes. (Corburn 2005: 3)

In contrast to a deficit model of "public understanding of science," in which expertise diffuses from sanctioned sites, Corburn emphasizes the co-production of forms of knowledge, as well as knowledge and governance. His vision is also geographically oriented, recognizing that reconfiguring boundary-work among science, technology and publics requires reconfiguration of the physical environments they inhabit and (re)produce together.

While this ecumenical perspective resonates in some ways with the contemporary ISE field, Corburn's distinctions between local knowledge and professional knowledge establish a framework for analyzing the social dynamics of knowledge that is missing from mere recognition of laypeople's knowledge derived from their everyday lives. This dissertation argues that such a framework is crucial for deeper understanding of and practices to advance public engagement with science and technology – at science museums and other ISE institutions, and beyond. As Corburn puts it:

> [*Street Science*] begins from the position that understanding the links between environmental pollution and public-health problems no longer can be viewed as a purely technical problem to be left exclusively to professionals. Concerned lay publics, especially the most disadvantaged populations experiencing the greatest risks and health problems, are demanding a greater role in researching, describing, and prescribing solutions for the hazards they face. (Corburn 2005: 3)

Thus not only do laypeople have knowledge, but their local expertise is vital to put in conversation with professional expertise. In addition, such expertise from the most marginalized, disadvantaged populations may be most vital to democratizing science and its applications, via technologies and otherwise. This perspective opens the way to taking seriously the social dynamics of expertise, in the context of social hierarchies and diverse decision-making fora. Simply moving away from a deficit model of science literacy is inadequate to these ends.

To contest such disenfranchising boundary-work, movements have sprung up ranging from "lay epidemiology" to "appropriate technology" to contest dominate paradigms of scientific research and its applications. Though these movements have varied substantive foci, they often assert that the "local knowledge" of people in a given place is valid and vital to shaping "the natural world" in which they live. Such knowledge is valid even though it may not be institutionally sanctioned as scientific, or articulate with dominant paradigms of development in which science and technology are often wedded to linear and technocratic processes of modernization. In these regards, sociological theories of everyday life, including theories of informal and tacit knowledge (Lave 1988), contest the authority of formal knowledge institutionalized in bureaucratic organizations and the industrial material culture thought to embody "development" as the application of scientific knowledge. At the same time, the notion of the "local" itself needs to be problematized, especially in the contemporary context of globalization.

"Putting Science in Its Place" – in a Deindustrializing, Digitizing Knowledge Society? Next Generation Environmental Justice Activism & the UN ICESCR's Article 15

The first wave of U.S. environmental justice activism, in the 1980s and 1990s, emphasized cleaning up or preventing pollution, especially the disproportionate burden of industrial wastes borne by low-income and communities of color. While these emphases remain core environmental justice issues, in subsequent decades, environmental justice activists have taken on additional issues to proactively shape industrial and urban development. For example, professionals and activists allied with environmental justice concerns have explored synergies between suburban "smart growth" policies and inner-city activism to addresses poverty and racial segregation. The green-collar jobs movement has also addressed these concerns, lobbying for jobs creation in renewable energy that simultaneously tackles racial and class divides. Next generation environmental justice advocates have mobilized not only at the level of local communities, but in terms of "metropolitan regional equity" and overarching patterns of urban and suburban development, both industrial and residential. And it is here that a "street science" approach to democratizing knowledge intersects with this dissertation's exploration of U.S. historical geographies and transformations of "the natural world" beyond museum walls, from the Fordist era of industrial museums to the post-Fordist era of science centers. While "street science," as discussed above, offers a promising critical framework for engaging the dynamics of expertise and "public engagement with science and technology," next generation environmental justice advocates and the green-collar jobs movement offer a promising framework for situating street science in contemporary political-economic dynamics and broader transformations of landscapes – including the complexities of mobilizing knowledge for justice in a so-called "post-industrial" knowledge society.

A helpful touchstone for thinking about science and publics in these terms is Article 15 of the United Nation's International Covenant on Economic, Social and Cultural Rights (ICESCR). Article 15 requires states to: 1) recognize the right of everyone to enjoy the benefits of scientific progress and its applications; 2) conserve, develop, and diffuse science; 3) respect the freedom indispensable for scientific research; and 4) recognize the benefits of international contacts and co-operation in the scientific field. In other words, Article 15 combines an emphasis on democratizing scientific knowledge as well as the fruits and applications of science – technologies that ameliorate everyday life, living standards and life chances, from electricity to medicines. This dissertation argues for the potential of this model of science popularization to help solve the cultural problem of "civilizing the machine in the garden," rather than deficit or diffusion models. It also argues that these concerns are a key addition to DIY initiatives such as

Maker Faires and science festivals. While the latter may have embraced popular culture in their exhibitions of the natural world, unlike elite science museums of the past, without greater attunement to political economy and geographies of everyday life, their populism will remain superficial. The "interactivity" and participation they offer publics will fall far short of truly democratizing science and technology.

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