Institutes for Innovation: the Emergence of Academic-Industrial Cooperation and Narratives of Progress in the Early 20th Century

by

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ABSTRACT

Early 20th century America is a critical context for understanding industrial innovation. Departing from a focus on innovation itself as manifested through the creation of new products and consumer opportunities, this project focuses instead on an important infrastructure for innovation – academic-industrial cooperation. Its particular emphasis is on the Mellon Institute for Industrial Research and the Massachusetts Institute of Technology. The Mellon Institute, an independent non-profit entity devoted to the promotion of industrial research, contributed not only through its novel scientific work, but also through its efforts aimed at engaging broad audiences through popular writing. As a competing model, this dissertation also examines interdisciplinary laboratories and administrative structures at MIT to argue that these schemes for academic-industrial cooperation that began as an informal series of ad hoc arrangements between researchers and corporate partners were increasingly formalized and centralized into a unique educational model that combined fundamental science and industrially relevant research. Rarely used archival materials are drawn on to argue that "narratives of progress," shared stories and rhetoric that were conceived for, and deployed in the service of, a particular idea of creating a better world through the enterprise of science were essential components of institutional and industrial change. Mechanisms for academic-industrial cooperation, no matter how well organized or funded, could not stand alone without a foundational narrative to give them broader purpose and context. Building on an institutional approach and employing a novel analysis of narrative as text, the built environment, and exhibit, this study offers new perspective on sites of academic-industrial cooperation as institutes for innovation.

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CHAPTER 1
INTRODUCTION

At the intersection of hope and pragmatism, a highly productive reaction could well be catalyzed through the coordinated efforts of individuals, ideas, and organizations held together by the cohesive force of narrative. In 1915, this productive outcome of such a synergistic process would have been called progress. In 2014, perhaps it is more likely to be identified as innovation. This dissertation project reveals one such reaction in the domain of applied chemistry, taking as its tool of examination the lens of early stage academic-industrial cooperation in the first decades of the 20th century. Academic-industrial cooperation is, of course, an entirely familiar if not taken-for-granted feature of the contemporary research landscape, but in 1900 that would hardly have been a foregone conclusion, given the nature of the 19th century academic enterprise as by and large an elite activity in an ivory tower, more concerned with ideas than intervention in industry or the economy more broadly. I take the early efforts of several key individuals at building an infrastructure for such cooperation, while simultaneously developing a rhetorical strategy by which to justify the rules of that cooperation, and to celebrate its successes, as an entry point for understanding the landscape of early 20th century innovation.

Innovation is both a product and a process of change; it transforms what might have been only possible into the pervasive or even prosaic through the scaling up of invention, a process that requires more than just technology per se, but the coordination of organizations and the infrastructure behind that coordination. Successful innovation goes beyond just turning dreams into reality. It is also the process by which ideas are transported from the cutting edge into the fully absorbed, and thus remarkably invisible, landscape of the ordinary world. Perhaps innovation is most widely identified through its tangible products: patents, inventions, and their associated consumables. However, in this dissertation project, I am most interested in the systems of organization and knowledge creation that are embedded in a technological landscape of things and ideas. Are there particular types of institutional or industrial settings that are better poised to innovate than are others? What are the institutional structures and organizational relationships that are necessary to catalyze the kind of change that will be beneficial to society? What kinds of relationships are necessary to foster innovation? How do discoveries become inventions; that is how do they transition from the laboratory into the broader societal landscape? All of these questions are well suited to historical inquiry – they are not only rooted in understanding processes of change over time, but also in the context of networks, social and economic structures that underpin these developments and the narratives of progress that they represent.

Industrial science is a particularly useful entry point into understanding innovation through its knowledge production and organizational practices; it is here that science and business most fully intersect. The concept of industrial science itself, created at the boundary between science and business, may be viewed as one fraught with simultaneous tension and synergy. On the one hand, the standard view of science as the pursuit of knowledge for knowledge's sake, disinterested in the entanglements of the world, may seem in conflict with the equally stereotypical view of business interests as solely driven by the desire for profit and market share. At the other end of the spectrum, perhaps science and business might seem inexorably linked, as creative economic drivers that build upon one another in a perpetual feedback loop of technology and capital. Both attempt to make productive order out of a messy world, find predictability in times of uncertainty, and wrest efficiency from an excess of waste. During the early 20th century, when I choose to focus this analysis, industrial science was beginning to emerge as a new field of research that could address industrial problems such as efficiency of production processes, waste minimization, material properties, all while grounded upon knowledge developed in the basic sciences. This nascent stage offers rich material from which to examine both the functional practice of industrial science through research and educational programs, as well as the narrative mechanisms by which leaders in this emerging field sought to establish legitimacy for their work and the associated ideas of societal progress through technological development.

Research agendas and educational programs are related mechanisms for producing knowledge, both through the creation of new ideas and the training of a skilled labor force. I approach the new-found quest for practical knowledge products and the organizational structures that surround them, not only as an intellectual or political process during the interwar period in the United States, but also a process of business strategy. I have selected the Mellon Institute for Industrial Research and the Massachusetts Institute of Technology (MIT) as my research sites for their distinct, yet complementary approaches to creating organized systems for the production of industrially relevant knowledge and labor. The measures they designed to connect academy and industry were not only aimed at improving the state of industrial development within the United States, but also conceived with an eye towards establishing a financially stable base of funding for institutions of research and higher education.

This period and location is particularly appropriate for this type of analysis because it captures simultaneously moments of economic prosperity and depression, rapid technological and scientific growth, a shifting political climate in a global context, and finally, crisis and transformation in higher education. A discussion of the coordination between academic scientists and industrial partners is well-suited to addressing the enterprise of innovation because they are both critical agents of technological change. In the United States during the early 20th century, in the lingering glow of the economic prosperity associated with the late 19th century boom in industrial production along with the development of urban markets, academics and industrialists alike wondered - how would the nation maintain this pace of development?

It is not surprising that along with the newfound wealth, productivity gains and increasing social mobility came significant growth in institutions that might be able to contribute to longer-term stability. This is especially evident in the rise of higher education structures, which both relied upon, and supported in turn, the human capital of what was undoubtedly a prosperous economy. However, economic success "was a necessary precondition but not a sufficient cause for the significant academic changes that took place."[1] In a country that enjoyed unusual levels of social mobility and a high influx of immigrants, the diversity and number of possible paths to "the American dream" also increased. The collegiate model, often popularly associated with elite

[1] Laurence R Veysey, *The Emergence of the American University* (Chicago: University of Chicago Press,

culture, Euro-centrism and intellectual separation from everyday society was increasingly called into question. What amounted to a time of genuine crisis for the American university system was one of opportunity as well. One response to the resulting sense of uncertainty was to create closer linkages between the challenges of the growing industrial sector and knowledge resources of the academy. These connections fostered both a growing emphasis on industrial applications for academic research products, as well as practical professional training for students, a phenomenon that was particularly notable in the scientific disciplines.

Chemistry provides a unifying subject area with which to approach early 20th century academic-industrial cooperation. In 1926, in the book *What Price Progress?*, Hugh Farrell urged investors to pay close attention to companies that "[kept] up with the times in the matter of new processes and methods of manufacture of fundamental resources,"[2] especially when it came to the field of chemistry. "Yesterday belonged to the mechanical engineer," he declared, referring to the mass production boom associated with the factory innovations of the so-called first industrial revolution, "but today and tomorrow belong to the chemical engineer – tomorrow more than today, for as great as has been the contribution of the chemical engineer to progress, he has only scratched the surface of his art."[3]

Research and development in chemical processes played a critical role in maintaining and creating new opportunities for competitive advantage. Chemistry offered several practical advantages over other scientific fields for potential return on investment in both corporate and academic settings. First of all, experimental practice most often included laboratory bench scale chemical work. Unlike building or testing

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[2] Hugh Farrell, *What Price Progress?* (New York: G.P. Putnam's Sons, 1926) 7.
[3] Farrell 10.

physical machinery (especially related to large scale factory production), a chemical lab required comparatively little investment in specialized equipment or large workspaces. Moreover, a single process could have several applications across different industrial sectors, making chemical work adaptable and flexible both physically and intellectually.

Perhaps the most widely studied manifestations of academic research and practical applications during the 20th century are in electrical engineering and related fields, especially as they relate to defense technology during and after WWII. However, my project focuses on an earlier period, between the World Wars, in chemistry-related disciplines. This context, I argue was necessary to have already established the organizational networks between research and production to later foster closer connections to government agencies and effectively mobilize for defense-related research in the mid-century. Between the World Wars, a "westward shift of world science" [4] from Europe to the United States occurred. Taking into consideration the overall political and economic climate, it is difficult to identify a single factor that catalyzed this shift. However, new investment in scientific research in the form of personnel, facilities and organizational structures played a significant role. Funding and collaboration structures varied distinctly and often were linked to specific fields of research and education. Private foundations became major supporters of academic science between the wars. State and federal funding at this time was mostly linked to agricultural projects and research, though this would begin to change during the Depression and the New Deal period that followed. Research in chemistry, on the other hand, was more likely to be funded by industry.[5] Although these funding trends

[4] Robert E. Kohler, "Science, Foundations and American Universities in the 1920s," *Osiris* 3 (1987): 135-164. Robert Kargon and Elizabeth Hodes "Karl Compton, Isaiah Bowman, and the Politics of Science in the Great Depression" Isis 76 (1985): 301-318

[5] Kohler 135-164. Kargon and Hodes 301-318.

continued, the disciplinary diversity for each of these types of funding sources would also increase after WWII, especially with the rise in government-supported defense projects.

However, the new interdisciplinary chemistry laboratories that arose between the wars, their research and curricula, and in some cases the associated university and industrial program offices offer particularly fertile sites for inquiry not only about scientific practice during this time of rapid change, but also about the surrounding structures of funding for research, curriculum development and the bureaucracy of oversight they required. Located as they were at the intersection of academic and corporate spheres, new interdisciplinary laboratories also provide a rich site for the study of boundary negotiations across disciplinary lines and types of organizational structures. Finally, they are a logical place to look for especially intense moments of institutional change, and to examine research and development efforts within regional economies. This context, where 'fundamental' science was combined with product-driven applied research is well suited for inquiry not only about scientific practice, but also about the process of innovation as it was understood by those actually engaged in it. We cannot overlook the unprecedented contribution of technological development to the overall productivity of the American economy and its workforce at this time, phenomena that has often been directly attributed to these applied research labs within academic centers and large corporate settings.

My study explores two institutional cases in particular: the Mellon Institute for Industrial Research and the Massachusetts Institute of Technology (MIT). Together they represent different cotemporaneous approaches to the connection of academic research to the challenges of American industry. Leaders at both of these institutions innovated, although in strikingly different ways, through the engagement of their respective research and educational agendas, in an effort to meet a variety of demands for technological expertise as well as to shape those demands going forward. The Mellon Institute was a primarily post-graduate research center founded in 1913 through the patronage of the Mellon brothers, Andrew and Richard, specifically to promote industrial research. Situated in Pittsburg, then a center for industrial innovation and American capital, the Mellon Institute not only produced research that would lead to new products and industries, but also framed new narratives designed to promote science and technology in the wider popular culture. In 1967 it merged with Carnegie Tech to form Carnegie Mellon University. MIT, founded in 1861 in Boston (and moving to Cambridge in 1916) developed a flexible model of education that linked research and basic science with industrial work. The MIT mode, which Etzkowitz called "entrepreneurial science,"[6] and Christophe Lecuyer has termed the creation of a "permeable university,"[7] is illustrated through my analysis of the Tech Plan, the Office of Industrial Cooperation, the Research Lab for Applied Chemistry and the Textile Research Laboratory, all of which found their roots in the early decades of the 20th century. Critical to both case studies, narrative and its use in fostering enthusiasm and legitimacy for science in industry and a particular concept of societal progress linked to technological change plays a unifying role at both institutions and serves as a topic in its own right.

In this study I am interested in a micro-level framing of institutional structures, as manifested in the organization of their departments, committees and programs, as well as their laboratories, research centers and educational activities. Since formative

[6] Henry Etzkowitz, *MIT and the Rise of Entrepreneurial Science,* (New York: Routledge, 2002).
[7] Christophe Lecuyer, "Academic Science and Technology in the Service of Industry: MIT Creates a "Permeable" Engineering School," *The American Economic Review,* 88 (1995): 28-33.

stages of organizational partnerships set the parameters for ongoing conditions, I focus on this critical nascent period of working relationships between academic and industrial scientists and business leaders. Whether these started as informal networks that became codified into bureaucratic processes, or began through formalized program structures, these relationships often led to broader organizational or structural changes through the creation of departments or offices of industrial cooperation that were in time associated with considerable financial commitments. Within these two primary institutional cases, my analysis includes two main categories: 1) organizational or administrative developments such as implementation of particular strategic plans, creation of offices, laboratories, and centers; and 2) new types of flexible educational models and programs including curricula, training and experience that incorporate industrial problem solving with fundamental science. I analyze change in organizational structures such as the creation of new offices, policies or laboratories, and focus on the impact of these programs on the classroom and research experience at the local level through curriculum development and degree programs. Finally, I engage the concept of industrial service in terms of influence on discipline formation within the applied sciences.

This study finds its origins in multiple literatures, each of which contributes a different position from which to approach innovation through the practice and narrative of industrial science in the early 20^{th} century. Business history offers one critical perspective on organizational change and the role of science within corporate strategy. The history of higher education in the United States contributes insight into the changing role of the university, curriculum development and philosophy of science and engineering programs. The turn to practice within science and technology studies

(STS) emphasizes the importance of understanding the everyday activities of science research. The study of material culture brings tools to approach first, the role of the artifact itself in the construction of narrative; second the role of objects in the academic-industrial laboratory; and finally, the way that scientific work is communicated through exhibition.

Technological change, institutional development, and innovation are well-established topics for inquiry within business history. I am influenced by this field, not only with respect to the similarities in topic, but even more so by the approach to big picture questions about technological and economic change through institution-building, the nature of their organizational arrangements, and through the decisions made by their leaders. In the foundational *Strategy and Structure (1962)* comparative study of the multidivisional structure, or "m-form" as it is commonly called, in four large corporations in different industries - DuPont (chemistry), General Motors (automotive), Standard Oil (energy) and Sears Roebuck (retail) - Alfred D. Chandler poses an "experiment in the writing of comparative business history."[8] At the heart of his project was his interest in the way that different enterprises went about doing the same activity. Chandler approaches this by relating *strategy*, "the basic long term goals and objectives" along with the actions needed to carry out those goals, to *structure*, "the organization devised to administer these enlarged activities and resources." [9] In my case, I am interested in how different institutions approach collaboration with industry through research and pedagogical practice. Furthermore I look for the particular organizational structures, such as the creation of specialized laboratories and offices,

[8] Alfred D. Chandler Jr. *Strategy and Structure – Chapters in the History of Industrial Enterprise.* (Cambridge: MIT Press, 1962)
[9] Chandler 13.

that they create to facilitate the strategy of increased academic-industrial interactions in both research and education.

The important role played by science as part of corporate strategy in the 20th c is a central theme in the foundational works of Chandler and David Noble.[10] Likewise in *Science and Corporate Strategy: Du Pont R&D, 1902-1980,* David A. Hounshell and John K. Smith characterize the industrial research laboratory as an institution new to both science and the corporation. In the case of Du Pont, a leader in the chemical industry, especially as it related to textile development, their work serves as an excellent model for the systematic study of a large corporate laboratory structure. Citing General Electric, Du Pont, Eastman Kodak, and American Telephone and Telegraph as pioneers in US industrial science. Hounshell and Smith assert that even in large successful firms such as these, which became known for their research divisions, the industrial laboratory emerged from smaller informal efforts, not unlike the case of nascent applied labs and corporate partnerships that I have observed thus far in the academic context. They argue that "science has been a dynamic element, changing and being changed by other elements of corporate performance," without a singular model of strategic development.[11] Graham and Pruitt describe the industrial laboratory as "an institution suspended between two worlds – that of industry and the marketplace, on the one hand, and that of the scientific professions, on the other."[12] This is also a useful way to characterize the laboratories and offices in my study, although they are primarily located in an academic rather than an industrial context. Using these works as a guide

[10] See: Alfred D. Chandler Jr. *Strategy and Structure – Chapters in the History of Industrial Enterprise.* (Cambridge: MIT Press, 1962) and David F. Noble *America By Design - Science Technology, and the Rise of Corporate Capitalism.* (New York: Knopf, 1977)
[11] David A. Hounshell and John Kenley Smith. *Science and Corporate Strategy: Du Pont R&D, 1902-1980.* (New York, NY: Cambridge University Press, 1988)
[12] Margaret B.W. Graham and Bettye H. Pruitt. *R&D for Industry A Century of Technical Innovation at Alcoa.* (Cambridge University Press. 1990) 3.

to parse the complexity of laboratories within a large corporate structure, I propose to add new perspective with my focus on the educational enterprise through an examination of the built environment and institutional narrative.

The rise of engineering education in the United States at the end of 19th century has been broadly characterized by historians as the emergence of a "practical" education, that is, an education fashioned in the service of industrial innovation and of necessity liberated from the earlier model of an elite pursuit contained within 'ivory towers.' In his foundational work, *America By Design*, David Noble characterizes this period in engineering higher education as "the wedding of science to the useful arts,"[13] a practice driven strategically by the needs of corporate capitalists, who stood only to gain by the creation of a sustainable skilled workforce in collaboration with institutions of higher education. W. Bernard Carlson, a historian of science and technology, adds nuance to this straightforward characterization of corporate agency to include "institution builders" from within the academy such as MIT's Dugald Jackson, chair of the Department of Electrical Engineering, who championed the cooperative course between MIT and General Electric from 1907 to 1932. Jackson helped to shape engineering education according to the priorities of his own academic institution through collaboration with industrial partners despite the initial reluctance of corporate leaders.[14] My project will also evaluate the role played by influential individuals in the development of industrial science, such as the early leaders of the Mellon Institute, Robert K. Duncan, Edward R. Weidlein and William A. Hamor.

Reliance on engineering schools to create a workforce suitable for a changing industrial nation is, unsurprisingly, not only an American story. Although my project

[13] Noble 20.
[14] W. Bernard Carlson, "Academic Entrepreneurship and Engineering Education: Dugald C. Jackson and the MIT-GE Cooperative Engineering Course, 1907-1932." *Technology and Culture* 29, 3 (1988): 536-567.

focuses on two institutions located in the northeastern United States, I am also influenced by scholarly work that originates outside of this geographic scope. Charles Day and Joel Andreas, working respectively in the French and Chinese contexts, likewise explore issues around the creation of educational structures for engineering entangled with concerns about social class and larger notions of progress as defined by government leaders.[15] Day argues that intermediate technical education exemplified by the *Ecoles des arts et métiers* opened opportunities for social mobility through technical education as new groups of workers (manufacturers, technicians, skilled workers) who did not fit into the existing educational structure, emerged to meet the challenges of the industrial age. The system that evolved outside of mainstream public education was situated between the highly-centralized more rigid and elite-oriented *Université* system of public education established by Napoleon which emphasized classical languages and humanistic culture and a more basic vocational training system.[16] This argument challenges common conceptions of the French social and educational system as closed and technology as 'more backward' during the mid-late 19th and early 20th centuries. However, Day emphasizes that there is a notable limit to the educational social mobility provided by the intermediate technical education since the middle-managers and supervisors created by this system were a new group, neither elites nor workers. For Andreas, the 'red engineers' are also a new socio-educational class. In this case, Andreas argues that after the Cultural Revolution in China, this group, modeled after the Soviet technocracy, was shaped through conflict and cooperation between the new

[15] Day, Charles. *Education for the industrial world: the écoles d'arts et métiers and the rise of French industrial engineering*. (Cambridge Mass: MIT Press, 1987).
[16] This included *lycee* and colleges culminating in *baccalauréat* exams and possibly entrance into the *grandes ecoles* and higher professional schools for the bourgeoisie. Education available for the sons of the petit bourgeoisie included the lower-level elementary system with higher primary schools aimed at training teachers.

political elite and the old educated elite. Rather than class-leveling, the result was rather the conversion of engineers "from enemies into champions of cultural capital."[17] Andreas' study of educational structures shaped for specific regional industrial and political development is exceptionally interesting in the communist context. For my own work, I take his study as a check to balance the dangers of becoming inadvertently isolated in a capitalist or American-exceptionalist narrative of industrial and educational development. In addition, the way that Andreas constructs his research plan around a single school, Tsinghua University, not as a typical environment but rather as a site located at the pinnacle of the Chinese educational system that was a critical component for credentialing both scientific and political leaders, is particularly useful for my own project that also builds on specialized educational institutions and their impact on a regional economy.

The push for practical knowledge products from the university represented not only an intellectual or political shift, but also one of business strategy. These measures designed to transform abstract knowledge into tangible products and processes were aimed not only at improving the state of industrial development within the United States, but also were conceived with an eye towards establishing a financially stable base of funding for institutions of higher education. In *MIT and the Rise of Entrepreneurial Science,* Henry Etzkowitz characterizes MIT as the first "entrepreneurial university," a result of the strategic mixing of disparate post-secondary models including the American "land grant," European polytechnic, the research university, and the classical teaching college.[18] This entrepreneurial shift is critiqued by scholars such as Christopher Newfield who, skeptical of the influence of business on the academy,

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[17] Joel Andreas, *Rise of the Red Engineers, the cultural revolution and the origins of China's new class.* (Stanford: Stanford University Press. 2009)
[18] Henry Etzkowitz, *MIT and the Rise of Entrepreneurial Science,* (New York: Routledge, 2002).

characterizes the modern research university system as a bureaucracy of its own self-entrenchment occupying an internally conflicted space between creating intellectual freedom from the entanglements of the corporate capitalist world and aspiration to it in terms of management and efficiency metrics. In *Ivy and Industry,* Newfield brings foundational studies from the history of education and business, for example those of Veysey and Noble, into dialogue with social theory, notably Foucault, to analyze primary source materials taken from university archives.[19] I take this as a useful model for the successful integration of primary documents and engagement with existing scholarship and more abstract theoretical analysis.

The "land grant" university, often connected closely to the disciplines of agriculture and the "mechanic arts" (engineering), was especially committed to research based on particular regional problems. In the case of MIT (although admittedly not a typical land grant institution[20]), this idea was most evident in its connections to regional industries in the Northeast United States, including textiles among many others. From the polytechnic model came the integrated relationship between science and technology as "interrelated and mutually supportive activities with a common purpose," that Etzkowitz describes as the "rationalization of the production processes of existing industries and the creation of new industries from scientific discoveries." [21] From the classic model of the teaching college came not only the expected focus on the quality of undergraduate teaching, but also the curricular inclusion of "pure" subjects in the sciences and humanities to balance out the "practical." Finally, from the model of

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[19] Christopher Newfield. *Ivy and industry: business and the making of the American university, 1880-1980.* (Durham: Duke University Press, 2003)
[20] MIT was founded within the "land grant" and "sea grant" program; however, unlike more typical "land grant" schools it was neither part of a large state funded system nor included agricultural science in addition to 'mechanic arts' (engineering)
[21] Etzkowitz

the Research University came also the ideal of academic autonomy.[22] Recognition of the transformation of MIT as an applied engineering school into an elite, yet practice-oriented research institute in the early 20th century is not new to the field of science and education history. Scholars such as David Noble, John W. Servos, Christophe Lécuyer, Henry Etzkowitz and Philip Alexander, among others, provide an excellent foundation on this topic in broad terms of university and industry relations.[23] They have also documented the transformations in personnel and curricula that took place in a number of large departments such as Physics, Chemistry and Electrical Engineering, all recognizable today as core disciplines for engineering practice. Perhaps Jon W. Servos' work on the chemical engineering department at MIT from 1900 to 1939 is the most closely related to my own project. In his paper, "The Industrial Relations of Science," Servos begins with the question "how did industrial patronage affect the evolution of academic science, basic and applied?"[24] He notes that MIT was among the initial American schools to develop structures for industrial research, following the lead of German firms that had successfully developed links between industry and university laboratories several decades earlier.[25] The debate surrounding appropriateness of engaging industrial research questions between leaders in the fields of chemistry and the emergent chemical engineering program also is a major theme that I have observed thus far in the case of textile science at MIT during the same time period. Through the case of textile science, which was related to chemical engineering, chemistry, physics and mechanical engineering at this time, yet not clearly associated with the industrial

[22] Etzkowitz
[23] In addition to those previously mentioned see Christophe Lécuyer, "Patrons and a Plan," in *Becoming MIT: Moments of Decision*, ed. David Kaiser (Cambridge: MIT Press, 2010), 59-80.
[24] Servos, John W. "The Industrial Relations of Science: Chemical Engineering at MIT, 1900-1939." *Isis* 71,4 (1980): 531-549.
[25] See also John J Beer, *The Emergence of the German Dye Industry*, (University of Illinois Press, 1959).

collaborative successes of the Research Lab for Applied Chemistry (RLAC), my intention is to build further complexity into this story by studying multiple disciplinary boundaries that converge upon common objects of both analysis and development, namely fibers and textiles.

This project also draws on the scholarship from the disciplinary 'turn to practice' in STS in which the everyday actions and material culture of the laboratory play a central role. Clarke and Fujimura's volume of collected essays, *The Right Tools for the Job* (1992) focuses on the way that scientists adapt both their methods and research questions around their tools. Employing a variety of case studies ranging from plasmid prep, drosophila and maize in genetics to taxidermy, these authors show that both tools and methods are dynamic, adaptive, and always subject to change. This is nicely highlighted by the case of taxidermy, which is characterized as a necessary foundational method for the bureaucratization and standardization of biological practices, although it is no longer prominently practiced. Taking their case as a model, I am also interested in the early stages of textile science and other industry or product specific disciplines as precursors to more generalized fields such as materials science and chemical engineering.

I then follow the STS literature outward from the immediate lab environment into a broader institutional context including laboratory placement in the sense of both bureaucratic structures and physical spaces. Analysis of the physical environment and particular facilities and equipment that contributed to professional identity formation also informs my study. Traweek's *Beamtimes and Lifetimes* (1988) focuses on physicists in California and Japan and how the time that they are allotted at the particle accelerator (a massive piece of scientific apparatus both in physical size and operation cost) for their experiments determines the potential success of their careers as a whole. Similarly, Downey's portrayal of early CAD/CAM technology in *The Machine in Me* (1998) demonstrates how the engineers he studied defined their careers around a particular version of the CAD/CAM software, noting in particular that they themselves could also become outdated as an extension of the technological interface in which their work was embedded. Despite the comparatively low appeal among scientists for things such as large-scale weapons, Gusterson shows how the particularly isolated testing facilities and associated practices of secrecy created a culture of practice and cohesion among weapons scientists in *Nuclear Rites* (1996). These works aid me in posing questions of professional identity formation based on both field affiliation and the conditions associated with various working environments. For example, in my study of the textile research laboratory at MIT in the 1920s and 30s, I analyzed written communications between scientists and administrative leaders about their opinions of relevant research questions in textile science and how these related to their characterization of appropriate disciplinary jurisdictions within chemistry, applied chemistry and physics. Through further analysis of similar laboratories collaborating with industrial partners at MIT in the early 20^{th} century, such as the much larger Research Laboratory of Applied Chemistry (RLAC), I also contextualize this particular research space within broader institutional structures.

The materiality of knowledge formation plays an important role in my analysis, especially as it was manifested through the built environment and communicated through display. The object-conscious narrative is particularly useful for understanding not only laboratory practice, but also communication strategies for public engagement that employ everyday products of industrial science. Unlike art objects that are designed to convey meaning through display, ordinary objects on the other hand, which may be associated with their usefulness as tools in manufacturing or other kinds of work, gain meaning through interaction with people and the transformation of raw materials. The use of artifacts in exhibits also give them new meaning, as they are explicitly interpreted for a visitor. Objects may bridge communities of practice and their working contexts or possibly serve as markers of particular jurisdictions among actors. The factory and training school, just like the contemporary university contexts, both involve the design and active use of a technology, though they may differ in scale. In some cases, industrial research centers serve as a bridge between the theory grounded in the academy and the practice carried out on the shop floor. The exhibit context on the other hand, serves to strategically 'un-black-box' technologies of production in an effort to educate laypeople or outsiders, who are also often the consumers of the produced goods in question. Technologies placed on display, either to illustrate historic or contemporary production processes then become not only tools, but often symbols for the act of knowledge production itself.

In their study of the heterogeneity of scientific practice through a case study of the Museum of Vertebrate zoology at Berkeley, a place that is built on a partnership between amateurs and professionals whose practice largely involves the negotiation of classification systems, Susan Leigh Star and James Griesemer offer a useful concept to combine the study of objects with institutional structures. Here they define 'boundary objects' as those which "both inhabit several intersecting social worlds and satisfy the informational requirements of each … plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites."[26]

Lorraine Daston and Bill Brown provide me with insight for approaching the role of artifacts as "things," as part of the noticeable and noteworthy world rather than merely as passive 'objects.'[27] Brown's *Things* offers a scene from an A.S. Byatt novel as a way to assign "thingness" – a person is gazing through a dusty window and does not recognize the window itself as a thing until acknowledging its opacity. This characterization transforms an artifact from a tool to look through, into something that explicitly acts on the observer; in this process it is rendered noticeable. For both Daston and Brown, thingness is a form of emergent agency, a much-analyzed quality in STS scholarship. Andrew Pickering's "mangle of practice" is particularly useful for highlighting the emergent yet ephemeral nature of non-human agency demonstrated by the bubble chamber in the physics laboratory. In the context of Dr. Glaser's bubble chamber, Pickering makes a critical distinction between humans in a scientific system who engage in future planning and have personal motivations, and non-human actors such as bubble chambers which gain agency through either their role as a facilitator or obstacle in the experiment. In this context the experiment is an iterative dialogue or

[26] Star, Susan Leigh and James Griesemer. 1989. "Institutional Ecology, "Translations," and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-1939." reprinted in Mario Biagioli, ed. The Science Studies Reader. (Routledge, 1999) 509.

[27] Daston challenges her readers to "imagine a world without things…" and goes on to describe the world as a 'porrigy oneness' with nothing to 'stub your toe on.' This work highlights the ability of things to convey meaning through materiality, but warns against ventriloquism of an object. "The things in these essays talk: they do not merely repeat. They are not instruments for recording and playing back the human voice." She goes on to make a distinction between two main epistemological categories of things: idols on one hand and on the other, the self-evident thing that 'speaks for itself' (*res ipsa loquitur*). I will argue however, technologies of production do not fit squarely into these categories, and may even navigate between them. Despite these differences, using Daston's approach, may be useful to think of large-scale labor-saving production technologies or standardized chemical methods not solely as replacements or enhancements of human action, but rather introducing a new kind of hybrid action.
Bill Brown, *Things*. (Chicago: University Of Chicago Press, 2004).
Lorraine, Daston, *Things That Talk: Object Lessons from Art and Science*. (New York; Cambridge, Mass.: Zone Books ; MIT Press [distributor], 2004).

negotiation between a scientist and materials of practice. Although I do not employ this approach explicitly in my work, this post-humanist, symmetrical treatment of humans and non-human actors helped me think about the built environment, archival documents and artifacts on display as actors in their own right.

Materials and Methods

For this study, I draw upon a combination of unpublished archival materials and published works, both books and periodicals. The majority of my primary source material is from the Mellon Institute records (held at the Carnegie Mellon Archives) and the MIT Archives. At both of these institutions, I was interested in learning about the way that research functioned in practice at a local level as well as how it was conceived and managed on a larger institutional scale. In order to understand these aspects, I examined a wide variety of materials including correspondence, speeches, annual reports, bulletins and pamphlets, scholarly articles, lab notebooks and reports, contracts, photographs and building schematics. Although only a small fraction of my archival materials are directly quoted within my text, all of these sources helped me to gain a clearer picture of my historical subjects.

I approach my archival materials both as traces of historical events as well as artifacts in their own right. For example in the chapter that focuses on the Mellon Institute, I analyze the fellowship agreement documents as not only contract records but also physical artifacts of the filing system in which they would have been embedded. Removed from this original system and now in the context of a quite different scheme of archival storage it is easy to overlook this dimension of material organization, a quality that at the time was notable enough to warrant its own article in the *Industrial and Engineering Chemistry.* As a researcher embedded in a digital world, I am especially conscious of both the technologies that I use to record, document and reexamine my own observations and analyses of these archival materials. Material qualities such as the weight of carbon paper versus luxurious hotel stationery, the color or flourish of a particular fountain pen or the hasty scribble of pencil notes on the text of a speech all contribute to the way that I read archival materials, yet may not get translated into the black and white copies or even digital photographs in my own personal archive.

I also used published books by Duncan, Weidlein and Hamor. When possible I purchased my own copies of these works. Withdrawn from college libraries, research centers and personal collections, these copies with their marginalia left by previous readers are different from the pristine versions held at the Chemical Heritage Foundation Othmer Library that started my search. Although these markings themselves do not find their way into my text explicitly, they make me think about the people for whom these authors were writing as both real and imagined publics. I wonder, perhaps as Duncan or Weidlein and Hamor once did, what other books sat beside these on all sorts of shelves across the country, and even some abroad. According to Dr. Holland's speech at the dedication of the Mellon Institute in 1915, even the king of Spain was reading Duncan's *The New Knowledge.*[28]

In order to get a sense for the chemical industry from the perspective of businesspeople, I read trade journals such as *Chemical Industries* and *Chemical Markets* as well as *Nation's Business* and *Fortune.* The majority of this work was done while in residency at the Chemical Heritage Foundation Othmer Library in Philadelphia. The

[28] Carnegie Mellon University Archives, Mellon Institute Archives "Address at Dedication of Mellon Institute March 26, 1915"

Hagley Museum and Library in Delaware was also a major source for business and industry materials. This institution holds the complete transcripts (1916-1985) for the National Industrial Conference Board (NICB), (which was renamed The Conference Board in 1970). These are an excellent resource for putting social and economic issues into context of the business community. These records include meetings that were broadcast over the radio as well in more private settings. Unlike the more common forms of meeting records such as minute summaries and agendas, these transcripts provide a full record of the conversation.

Interest in industrial chemistry on display brought me to the Smithsonian Institution Archives in Washington D.C. The records of the Section on Chemical Technologies were influential in my analysis of narratives of progress through exhibitions. In addition, this archive also holds the records from the Science Service publication, another mechanism through which contemporary science was communicated to a broad American audience.

Additional research sites included the Center for Lowell History, Lowell MA (UMass Lowell institutional archives), American Textile History Museum, Lowell MA (materials related to local and national textile manufacture, artifacts including equipment such as looms and testing apparatus, photographs), Harvard Baker Library (US textile company records).

CHAPTER OUTLINE

This dissertation is divided into three main chapters. The first two are case studies that focus on a particular institution: first the Mellon Institute for Industrial Research; and second, MIT. The third chapter addresses "narratives of progress" through text, the built environment, and display, drawing upon examples from both institutions along with the Smithsonian Institution's Section on Chemical Technology. Finally, the conclusion revisits some enduring questions about innovation and its institutional structures.

Chapter two, *"Science in Action:" Duncan's Industrial Fellowship Program and The Mellon Institute for Industrial Research*, presents the industrial fellowship system first developed at the University of Kansas, that later gave rise in the first decade of the 20th century to the Mellon Institute. In this form, the fellowship program provided the foundation for an independent non-profit entity devoted to the promotion of industrial research. I examine the creation of the first fellowship at the University of Kansas through the body of correspondence between Robert Kennedy Duncan, a chemistry professor at the University of Kansas, and E. Ray Speare, a Massachusetts-based businessman. The development of this negotiation not only sets the foundation for the mechanics of the program to be, but also reveals insight into cooperation between these two types of actors. Not only did the Mellon Institute contribute to the field of industrial research through its scientific work, but also through popular writing aimed at a broad audience. The general publications of the Mellon Institute's leaders, Duncan, Weidlein and Hamor are introduced in this chapter and then more fully explored in the final chapter on "narratives of progress." I argue that, ironically, the success of the

Mellon Institute and its efforts to promote industrial science as a legitimate and valuable field also ultimately contributed to its obsolescence as in-house laboratories became integrated into small and medium sized companies, whereas earlier they were only found at large well-established corporations. At the same time the general trend in academic science placed an increasing emphasis on government-funded basic research. Finally, I contextualize this often nationally-centered story in a broader international network through a series of correspondence from the Mellon Institute leaders while traveling abroad back to their colleagues at home.

Chapter three, *"A Technological Education:" Entrepreneurial Vision and Educational Strategy at the Massachusetts Institute of Technology,* addresses academic-industrial research with an emphasis on the role it played in MIT's overall educational program. Through specific cases such as the Tech Plan, the Office for Industrial Cooperation, the Research Laboratory for Applied Chemistry, and the Textile Laboratory, I examine the way that educational strategy was used in the 1920s and 30s to both address emerging needs in industrial science as well as increase the prestige for engineering and practical science through close alignment with basic science. I argue that this scheme that began as an informal series of ad hoc arrangements between researchers and corporate partners was increasingly formalized and centralized into what we now believe to be an enduring and flexible model.

Chapter four, *Narratives of Progress and Innovation: a landscape for technological imagination,* addresses the use of shared stories designed to describe and promote particular visions of the future based on technological development. I analyze narratives of progress through the texts of Mellon Institute leaders and speeches of MIT's president Karl T. Compton. I then extend the notion of narrative to include its manifestation throughout the built environment, such as academic buildings and exhibits. In addition to examples drawn from the Mellon Institute and MIT, I introduce a third "institute for innovation," the Smithsonian Institute's Section on Chemical Technology. I argue that narratives of progress were essential components of institutional and industrial change across the critical first few decades of the 20th century. Mechanisms for academic-industrial cooperation, no matter how well organized or funded, could not stand alone without a foundational narrative to give them broader purpose and context.

CHAPTER 2
"SCIENCE IN ACTION:" DUNCAN'S INDUSTRIAL FELLOWSHIP PROGRAM AND THE MELLON INSTITUTE FOR INDUSTRIAL RESEARCH

In 1907, Robert Kennedy Duncan posed a deceptively simple question, "how can we utilize modern knowledge?"[29] For Duncan, then a chemistry professor at the University of Kansas and a prolific writer on science for popular audiences, the answer to this question called for an increased role for science as a productive agent of efficiency and coordination, and as a means to what he called "an era of gracious living."[30] Duncan's belief in applied science as a necessary and indeed urgent tool for progress echoed throughout his public writing; in popular magazines such as *Harper's Monthly* and in his three books he fervently advocated the application of academic research to industrial problems.[31] Duncan's work served as a powerful catalyst that caught the attention of and garnered support from many industrial leaders. His efforts sparked the development of an industrial fellowship program that would serve as a model for academic-industrial cooperation for the next decade with the creation of the Mellon Institute for Industrial Research. This mainly post-graduate research center, a so-called

[29] Robert K. Duncan *The Chemistry of Commerce* (New York and London: Haper and Brothers, 1907) 246.
[30] Duncan *The Chemistry of Commerce*, xii
[31] Duncan's books included: *The New Knowledge* (New York: A.S. Barnes, 1905), *The Chemistry of Commerce* (New York and London: Haper and Brothers, 1907), and *Some Chemical Problems of Today* (New York and London: Haper and Brothers, 1911)

"armory of applied science,"[32] founded in Pittsburgh in 1913, played a foundational role in shaping the emerging American R&D sector. Within its first 25 years of operation alone, the Mellon Institute had already served 3600 companies from a wide variety of industrial sectors (either as firms or members of trade associations), an unprecedented figure for the time. Out of these collaborations came 500 novel processes and products, and from them ten new industries were created.[33] Over the quarter century that followed, the Mellon Institute continued to shape the landscape of American R&D as collaborative fellowship projects in some cases grew into in-house corporate laboratories. Some large corporations such as General Electric and DuPont had their own research divisions from early on, yet the majority of smaller companies began their research activities through collaborations with institutes and universities similar to the Mellon Institute fellowship model. By the time that the Mellon Institute merged with the Carnegie Institute of Technology to form Carnegie Mellon University in 1967, laboratories in large corporations had become more the norm than the exception. By the 1960s, Mellon's researchers had contributed more than 4,700 papers and 1,600 patents to an academic research ecosystem that, fueled by substantial increases in government funding, then began a shift away from applied and toward fundamental science.[34]

Indeed, perhaps the end of the Mellon Institute for Industrial Research as an independent entity in 1967 after successfully promoting the growth of industrial science should actually be read as a signifier of its success. Mellon Institute leaders had not only

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[32] Edward R. Weidlein and William A. Hamor, *Glances at Industrial Research, During Walks and Talks in Mellon Institute,* (New York: Reinhold, 1936) 12.
[33] Weidlein and Hamor, 12
[34] American Chemical Society National Historic Chemical Landmarks. Mellon Institute of Industrial Research. http://www.acs.org/content/acs/en/education/whatischemistry/landmarks/mellon-institute.html (accessed April 01, 2014).

produced a wealth of papers and patents, but also powerful narratives of progress. These narratives served both to bolster the prestige of industrial science and to link this new type of work with their vision for an enhanced quality of life (see chapter 4). In 2013, the American Chemical Society designated the Mellon Institute of Industrial Research, now part of the campus of Carnegie Mellon University, as a National Historic Chemical Landmark.[35]

This chapter offers a new look at the critical early activities of the Mellon Institute for Industrial research, drawing on as yet unpublished archival materials. My goal is not to present an institutional history but rather to examine early stage academic-industrial partnerships and the related growth of new organizational forms to facilitate industrial science based in applied chemistry. The work of Robert Kennedy Duncan – in particular, his popular science writings, his role as a foundational institutional entrepreneur, and his creation of the industrial fellowship program - all serve to illustrate the development and coordination of a research system in the service of a particular model of human progress. This idea of applied science as a facilitator of progress would later become universally recognizable, or even perhaps notorious, in the slogan adopted by the DuPont Corporation, "better living through chemistry."

The body of correspondence that gave rise to the industrial fellowship at the University of Kansas (the precursor for the Mellon Institute model) offers a window

[35] Text from the plaque dedicated at Carnegie Mellon University on March 28, 2013 "The Mellon Institute of Industrial Research was established in 1913 by Andrew W. and Richard B. Mellon to conduct comprehensive scientific investigations that would serve industry and benefit mankind through the development of industry. The Institute provided research services from its inception through World War II, at a time when relatively few manufacturers operated research laboratories of their own. Hundreds of scientists were trained in fundamental and applied research, many of whom went on to careers in industrial research and development, and companies such as Dow Corning Corporation and the chemical division of Union Carbide Corporation were founded on research performed at the Institute. Located in this building since 1937, the Mellon Institute merged with the Carnegie Institute of Technology in 1967 to form Carnegie Mellon University."

into the early stages of academic-industrial cooperation. I analyze the way the letters between Duncan and his first industrial partner highlight the process by which an academic and an industrialist might develop a scheme for a mutually beneficial research project. Theirs would become a widely applicable model for academic-industrial cooperation, serving as the basis for the formation of the Mellon Institute for Industrial Research. I emphasize the organizational components of innovation, using specific examples from the fellowship agreement files. These agreement documents and the organizational system created to utilize the relationships they represent offer rich material from which to understand these documents' multiple roles as scientific, administrative, and legal transactions. Finally, I employ the personal accounts of Mellon Institute Director Edward Weidlein's travels abroad in 1927 and 1956 to challenge the common narrative of industrial science as merely a regional or at most a national practice. Rather, my work makes explicit the international network in which Mellon's early leaders operated and which nurtured their ideas.

Origins of the Industrial Fellowship System

The first fellowship did not arise from a policy created by a board of trustees nor a formalized strategic plan. Although it set a precedent for academic industrial cooperation and offers a model for future dealings between these two types of actors, it was initiated neither around a meeting table nor in a club lounge. Rather, this collaboration was catalyzed through the public writings of a chemistry professor published in a variety magazine aimed at a broad audience. Although the fellowship concept would later provide a basis for outreach on the part of academic leaders to approach potential industrial partners, it is worth noting that it began in the opposite direction, with a letter from an industrialist to an academic.

Robert Kennedy Duncan's series "The Chemistry of Commerce," published in *Harper's Monthly Magazine*, began in 1905 and concluded in 1907 after eleven sections ranging in topic from the chemistry underlying rare earth metals to the chemistry of medicine. These articles were aimed at a general readership, and were interspersed in the magazine with other serial features including topics such as romance, drama, law and history, poetry, travel, and cartoons and humor. Due to the popularity of the articles in serial form, Harper & Brothers published them as a book the following year. This 1907 edition of *The Chemistry of Commerce* was Duncan's second book, following *The New Knowledge*, published by A.S. Barnes & Company in 1905.[36]

In September of 1906, E. Ray Speare, an industrialist, read Duncan's article about cellulose in *Harper's Monthly Magazine*. He was the treasurer and general manager of Alden Speare Sons Co., a Massachusetts based firm that he described as specializing in "the manufacture of high grade laundry supplies, starches, soaps, bleaches etc." [37] For Speare, the chemical challenges of industrial scale laundry that Duncan described in his article were all too familiar. Confronted with what Speare characterized as a "resentful reference to the process in use for the cleansing of linen and cotton textiles"[38] in Duncan's article on cellulose chemistry, he reached out to Duncan with the hope of gaining access to "a little bit of the brain that lies back (*sic*) of such an article." [39]

In my research I employ the body of correspondence that followed from that initial query to explore both the conceptual and practical concerns surrounding the

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[36] There were two printings of this book, April 1905 and August 1905, an indicator of its popularity
[37] "E. Ray Speare to R.K. Duncan October 8, 1906" in Carnegie Mellon University Archives, Mellon Institute Documents Box 209, ff7664.
[38] Ibid.
[39] Ibid.

creation of a mechanism for academic-industrial cooperation through the formation of an industrial fellowship scheme. Not only did the correspondence illustrate the possible mechanics of setting up an industrial fellowship program, but it also provided context for the both shared and differing motivations and priorities of an academic scientist and a businessperson and how they converged in mutual agreement. While Duncan first formulated the vision for his particular model of academic-industrial research based in applied-chemistry, Speare grounded this theory and criticism in his own industrial experience. The main themes that Speare and Duncan discussed may be characterized as 1) the need for chemical research for industrial settings; 2) the practical concerns associated with setting up the fellowship; and 3) the assignment of value to restriction placed on knowledge generated through the fellowship. It is not surprising that the topic of intellectual property was the most contentious of the concerns that Duncan and Speare addressed in their letters.

The cordial negotiations between Duncan and Speare in their correspondence allow me to understand how their notion of progress was translated into actual projects and structures that furthered this vision. This idea of progress is addressed most directly in the final chapter, but it is worth noting here that the theme that I call "narratives of progress" is a thread that winds through this and the next chapter as well. This body of correspondence adds a more intimate perspective to a story of academic industrial cooperation that might otherwise be overlooked if studied solely in terms of policy outcomes and research output. The fellowship was a product of a compromise between science and business; the letters well illustrate the development of these arrangements.

While the Boston location of this industrial partner for the inaugural fellowship at the University of Kansas may be surprising, the nature of the laundry business, especially at an industrial scale, was quite well-suited to implementation of research in applied chemistry. When describing his industry to Duncan in his first letter, Speare noted the marked growth in the business in the United States and England due to mechanical improvements in laundry equipment. However, he also expressed the need for chemical, rather than mechanical solutions to problems in industrial laundry at this stage of development. He lamented that "the actual process of washing, the actual chemistry, of the laundry business has had but little attention. It has been taken for granted that the old process of washing, bleaching and bluing the good was right and the only marked advance has been in the turning out of higher grade product to perform these functions with little or no careful chemical attention to the actual improvement of the process itself." [40] For Speare, Duncan's article and advocacy for applied chemistry spoke to an issue that had been long weighing on his mind. He wrote, "I have felt for sometime the need of advanced ideas and actual chemical knowledge to improve the process of laundering and to insure a maximum of cleanliness with a minimum of wear on the goods so treated."[41] Speare envisioned that chemical improvements would both increase cleanliness and reduce stress on laundered goods. Stating that, "If goods are washed at home, the cleansing is partially chemical but largely physical. The dirt is practically pounded or rubbed out of the goods and the physical wear on the goods so treated is unnecessarily excessive. On the other hand, it is a well known fact that goods

[40] Ibid.
[41] Ibid.

washed in the most modern and up-to-date steam laundry ... [and] go to pieces in short order."[42]

He described leaders in the laundry industry such as himself as those who

> "would more than welcome advanced ideas. As a class they are heartily tired of the complaints of customers whose goods they destroy and no inconsiderable item of expense with them is the payment of claims to customers for good[s] damaged or destroyed by careless chemical handling."[43]

Process improvements should result in "reduced wear and tear on goods washed, and large economies in the cost of materials and labor at present employed in the laundry washroom."[44] Speare also saw the opportunity for increasing the impact of these potential improvements through the already established scope of his own business network, "through a force of salesmen that visit every steam laundry in the United States during the year." He acknowledged that not all process improvements would be universally popular, "I could bring about the adoption of sane methods that would certainly save the man who pays countless dollars, even though the 'textile industries' might suffer from loss of trade thereby."[45] This apparent tradeoff between prolonged lifespan of goods versus the need for new products also highlights the difficulty of characterizing an industry and its interests as a whole.

Although chemists were employed in some factories, they served in "works laboratories" that specialized in testing and control of existing products rather than in research aimed at developing new products.[46] Speare emphasized that these chemists were "fully occupied with dealing with the new products we work from in our

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[42] Ibid.
[43] Ibid.
[44] Ibid.
[45] Ibid.
[46] See Margaret Graham and Bettye Pruitt, *R & D for industry : a century of technical innovation at Alcoa*, (Cambridge and New York: Cambridge University Press, 1990).

manufacture, and, like many of the chemists I have come into contact with, their long work on specialized lines has made them men of few ideas, highly developed." [47]

In response to this first letter from Speare, Duncan acknowledged that he had received a great many letters from laundrymen in the US and England, but chose to respond to Speare particularly because his letter, unlike those from many of his peers, "showed real knowledge and because it was so broadminded and so sane and hopeful."[48] Throughout the exchange of letters between the two men, this tone of mutual respect for each other's specialized knowledge balanced with "broad mindedness" sets a foundation for their nascent business relationship.

Although Duncan himself couldn't spare the time to undertake such a project, he did offer another solution to Speare: "we have good men as graduate students…They know their business, they seem to have limitless energy, are trustworthy, and altogether a fine type of men, speaking generally, as I say."[49] He suggested a fellowship program aimed at addressing such practical industrial problems. The idea came from his own observations abroad, where he "found conditions of extreme significance" especially in Germany where he noted with enthusiasm that "universities, factories, banks and carrying companies, are coordinated into a most efficiently working mechanism." He told the "not uncommon" story of Professor Adolf Frank of Berlin who upon creating a new type of fertilizer approached a large manufacturing firm, Siemens and Halske. Together the professor and the company representative then went to the Deutsche Bank, which "employed its experts to decide upon the process." They then formed a new company including "the Deutsche Bank with its money, Professor Frank with his

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[47] "E. Ray Speare to R.K. Duncan October 8, 1906."
[48] "R.K. Duncan to E. Ray Speare October 13, 1906" in Carnegie Mellon University Archives, Mellon Institute Documents Box 209, ff7664.
[49] Ibid.

invention, and Siemens and Halske with their immense experimental facilities."[50] The arrangement that Duncan proposed did not mirror the German example. He envisioned the inventions and experimental facilities to be both housed at his university, and the financing to come from the sponsoring company. His purpose of telling this German story to Speare was to ground his idea in an already established example of productive coordination between apparently disparate entities to foster business development.

Duncan saw the fellowship program he proposed not only as a boon for the creation of useful knowledge, but also as a way to establish a stable employment path for his students. Indeed, Duncan's concept for the fellowship system quite consciously not only created roles for young scientists to gain experience through the individual project but also offered them opportunity for longer term employment at the sponsoring company. "Only because I have been impressed by the intelligence and broad mindedness of your letter,"[51] Duncan offered the proposition of a temporary two-year fellowship (for $500/year) to Speare. Duncan himself would advise and supervise the research of a fellow who was devoted entirely to the chemistry of laundering. He described the plan as he saw it,

> "the young man chosen should first of all thoroughly investigate the literature on the chemistry of laundering, and digest it all. Second, that he should go into a laundry or laundries, two or three in succession, and learn practically all of the chemical details of the business. Then knowing practically all there is about the subject, he should enter my laboratories, and work for his life." [52]

He laid out an ambitious plan for this young industrial fellow who would also at the end of the two-year term, ideally produce a book, "treating exhaustively and critically the chemistry of the laundry business." Duncan would help him find a publisher for this

[50] "R.K. Duncan to E Ray Speare November 10, 1906" in Carnegie Mellon University Archives, Mellon Institute Documents Box 209, ff7664.
[51] "R.K. Duncan to E Ray Speare October 13, 1906" in Carnegie Mellon University Archives, Mellon Institute Documents Box 209, ff7664
[52] Ibid.

book and "by that time I should expect him to have made some steps of practical importance, working as I say under my guidance and direction."[53] Warren Fred Faragher, a twenty-three year old chemistry instructor at the University of Kansas was selected as the inaugural fellow for Speare's laundry research. Described by Duncan as having "a splendid training and, as well, mental attainments of a high order," this young researcher was unanimously deemed the "best young man" in the Chemistry Department. He gave up a higher paying two year post with Sir William Ramsay in London for the fellowship position.[54]

Steeped in the ethos of the state university model, the idea of academic outreach to address pressing problems outside the university seemed to come naturally to Duncan. At the University of Kansas, though not the land grant state college, he had made the point that his sort of school, "with its ear to the ground, ...unlike those institutions that are concerned only with their own self-perpetuation," was able to hear " the murmurs of the people."[55] In other words, he knew how to identify pressing societal problems and turn them into opportunities for research. Duncan touted the qualities of his graduate students as, "better men on the whole than can be obtained in Eastern universities."[56] Despite being a trustee for such one Eastern university, namely Boston University, Speare was "so much impressed by [Duncan's] broad knowledge of the subject of Industrial Chemistry and believe that [his] own attention to this matter would be of such great value," that he then decided to recommend the proposed fellowship agreement to the board of directors of his firm. Although there were many other schools in closer proximity to Speare's Massachusetts-based business, he chose to

[53] Ibid.
[54] "R.K. Duncan to E Ray Speare February 7, 1907" in Carnegie Mellon University Archives, Mellon Institute Documents Box 209, ff7664.
[55] Duncan *The Chemistry of Commerce*, 253
[56] "R.K. Duncan to E Ray Speare October 13, 1906."

work with Duncan at the University of Kansas. The fellow would perform the research under Duncan's supervision in Lawrence, Kansas, yet would start the project with site visits to both the Chicago and Boston headquarters of Speare and Sons Co.

Refining the vision, Speare described his view of how the fellowship would work, echoing much of Duncan's original plan: "we assume you would pick for us some young man who has had more than a rudimentary training in chemistry, and therefore, in a position to specialize, and that this young man, as you suggest, post himself on the theoretical side of chemistry in the laundry as it exists today in very meager form. He should then go into some laundry and learn practically – as you state – all the chemical details of the business as it is conducted today in the cleansing parts of the laundry. He should then enter your laboratory, as you suggest, and work on the simplification of the methods and processes at present employed."[57] He asked for progress reports " from time to time" and offered more regular back and forth communication with the fellow as well since, "it is very possible that our own experience might enable us to supplement his work by offering suggestions … which might help in expediting his progress." [58]

Duncan and Speare both agreed that information should be shared in the form of periodic reports. However, the issue of knowledge sharing more broadly outside the particular partnership remained a point of contention. Although Duncan did not ask for any royalties on behalf of the university, he did suggest that "one tenth of the net profits of any discovery made during the course of this investigation should belong to the

[57] "E. Ray Speare to R.K Duncan October 31, 1906" in Carnegie Mellon University Archives, Mellon Institute Documents Box 209, ff7664.
[58] Ibid.

holder of the fellowship."[59] He considered this "a wise thing" which "would afford every possible incentive to the man's utmost efforts."[60]

Speare then offered some changes that from his point of view seemed necessary regarding the mechanics of the fellowship agreement. Not surprisingly all of these alterations related to proprietary information and the maintenance of competitive advantage through the proposed research collaboration. Public knowledge sharing would remain a point of contention throughout the negotiation. Speare made his role and position in the agreement quite plain, "Of course, this comes down, as you can readily understand, to a cold blooded business proposition with us, and, for this reason, we should discountenance the publication of a book making public property of the results of these investigations attendant on this work."[61] He reiterated, "our basis in considering a scheme of this kind is, of course, to make money."[62]

While the financial agreement was proposed between the university and the industrial sponsor, the intellectual property was shared between the research fellow and the sponsor. Speare made an effort to ensure a long term relationship with the fellow: "we would also want an understanding established with the young man whom you might pick for the work, to the effect that the expiration of this course, or prior to that time if the results obtained justified it, his services should be ours for a certain term of years – the terms to be mutually satisfactory. I think you will agree with me that this would be a wise proviso, as it would be only natural to suppose a case working out somewhat as follows: the man in question might make some valuable discoveries during this work, and, at the completion of the course, take the matter to our competitors and

[59] "R.K. Duncan to E Ray Speare October 13, 1906"
[60] Ibid.
[61] "E. Ray Speare to R.K Duncan October 31, 1906"
[62] Ibid.

let them reap the benefits which should rightly be ours for fathering the idea from its inception."[63] He agreed without reservation to the ten percent net profit benefit for the fellow. He emphasized, "we would want the holder of this fellowship to have every interest in working out this proposition and will be only too glad to make it worth his while – it being of course understood that any and all discoveries he might make during his course should be our property subject to the payment of the royalty you mention on the sale of such products."[64] It is worth noting that only the fellow would be entitled to royalties of any kind through this agreement and the university would get the right to publish findings from the research only after an agreed upon period of time, but would not have any role in licensing technologies or filing patents.

Just as Speare had adopted the role of the "cold blooded businessman," Duncan argued on behalf of knowledge sharing and invoked the point of view of the board of regents. In his role, he questioned the public benefit of the fellowships arrangements.

> "They would say: "What has the university got to do with it? And what have you, professor Duncan as a university official, got to do with it? It is simply for helping a factory and one young man?" Now on the other hand my original proposition, I can say with you that the industry is not fairly considered in this matter. You want the worth of your money and your risk." [65]

So Duncan offered a compromise in which,

> "the work of the proposed fellowship shall, at the conclusion of the two years, be written out for you and the university: that the university shall place this sealed report in its archives until the expiration of three years, when it shall be at liberty to publish the report. In this way the university confers knowledge on men, and you get the knowledge you want and three years' advantage of it." [66]

To further dispel Speare's potential concerns, he added,

[63] Ibid.
[64] Ibid.
[65] "R.K. Duncan to E Ray Speare November 10, 1906" in Carnegie Mellon University Archives, Mellon Institute Documents Box 209, ff7664
[66] Ibid.

> "as we both know, such a report, no more than a patent specification would contain all that is required for the application of whatever discovery might be made. After three years you personally would care nothing, with such a start, as to what was known three years before. The only possible hitch to a practical arrangement of this very important matter for American industry is this question of secrecy, and I am hoping that the compromise of the matter that I have suggested will be acceptable to you." [67]

In response, Speare agreed to the three-year protection plan provided that "it is understood that any patentable original ideas developed during this time should become the property of this Company, subject to a royalty payment to the inventor, we are prepared to carry out our agreement which we therein outlined."[68]

There were wider implications embedded in this carefully negotiated initial arrangement. Process improvements to the chemistry of laundry systems were just a single example in an open field of unmet industrial needs. Through these fellowships, Duncan's goals combined both knowledge production and labor to establish the role of science and scientists in industry. Although the arrangement between Duncan and Speare began as an individual arrangement, Duncan was keenly aware of the precedent for collaboration that they were setting, as well as the opportunity to create a model that would scale far beyond the interests of a single company or industrial sector.

With this potential for creating a model to promote the coordination of future industrial research, Duncan offered both his services and those of his university to generate publicity to promote Speare's "wise and generous action in establishing such a fellowship." [69] Duncan lauded Speare for his actions, which he considered to be "an innovation and one which it would do industry an incalculable amount of good to

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[67] Ibid.

[68] "E. Ray Speare to R.K. Duncan November 21, 1906" in Carnegie Mellon University Archives, Mellon Institute Documents Box 209, ff7664.

[69] "R.K. Duncan to E Ray Speare October 13, 1906."

follow."[70] Speare initially had no interest in publicity, fearing that publication "while working as a simple advertisement, [would] at the same time cause more or less annoyance by solicitations for the same purpose from other sources."[71] However later, when the fellowship carried the name of the late Alden Speare who was active in both education and industry, the prospect of publicizing seemed more appealing.[72]

Emphasizing the impact that he and Speare could have on the future, he forecasts, "the establishment of a fellowship of this kind would be an innovation and would have, I believe, ultimately, an importance in the relation of modern chemistry to industry and in the progress of American industry that could hardly be exaggerated."[73] With this in mind, Duncan urged Speare to project beyond their immediate concerns, "I am sure that you will agree with me, then, that we ought to arrange matters between ourselves in such a way that the arrangement will stand more or less as a model for all others between all universities and all industries."[74]

Duncan's fellowship plan addressed the need for skilled workers, efficiency and organization in American industrial centers. In his mind, it was only through coordination of these too often disparate actors that progress could emerge. He phrased this desire in terms of a system of networked benefits.

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[70] Ibid.
[71] E. Ray Speare to R.K Duncan October 31, 1906."
[72] "E. Ray Speare to R.K Duncan December 10, 1906" in Carnegie Mellon University Archives, Mellon Institute Documents Box 209, ff7664.
Alden Speare was "one of the original founders of Boston University, president of the board of trustees of the university at the time of his decease, a broad patron of educational methods during his life, and at one time president of our Boston chamber of commerce and also of our associated board of trade."
"in regard to your proposed article for the North American Review... any expression you might deem wise to make in reference to this fellowship and our connection with it, would of course, be very much appreciated by us and we should be much pleased to have you mention our name in connection with this in any way you see fit."
[73] "E. Ray Speare to R.K Duncan November 10, 1906" in Carnegie Mellon University Archives, Mellon Institute Documents Box 209, ff7664.
[74] Ibid.

> "Now, what interests me is some method by which I can bring into coordination the factories, the universities, and that not for the good of the factories alone, but for the good of the people and factories, and our young men, and for the increase of knowledge. At present the old established industrial processes are working at great waste and their efforts towards betterment are most haphazard. When they want 'good men,' and they always do, they do not know where to apply for them, and when they are confronted with chemical problems, and what industry isn't, they don't know what to do with these problems. They therefore need some kind of sympathetic cooperation with the universities where modern knowledge is to be found, and where young men are trained and recognized and found out. The university on the other hand exists for the increase of knowledge among men, for teaching young men, and for the promotion of the welfare of the people. This then is our problem. This cooperation in the form of a fellowship has got to be good for you and it has got to fall into line with our work or else it is not practical."[75]

Duncan reiterated the importance of the precedent that they were setting.

> "Please draw up your agreement statement in as liberal a spirit as possible, remembering that the University is entering upon this work solely for the purpose of increasing useful knowledge and that in order to do this it is extending help to you. If this fellowship is brought to a successful issue it is going to initiate a great change in American industry…PS I need hardly say that we want to make this agreement between you and the University as a model which will stand for all coming ones of this kind. It ought to be drawn in a broad spirit and written in a dignified way." [76]

This remarkable body of correspondence helps us to gain insight into both the personal motivations for, as well as the practical concerns associated with the creation of academic-industrial research collaborations. The negotiation between Duncan and Speare, both representing the viewpoint and interests of their respective professional worlds, serves not only to highlight the difficulties of assigning knowledge and value between industrial and academic entities, but also to suggest a way in which they might be resolved. It is worth noting that this entire formative negotiation took place over a period of just over three months without meeting in person. The process developed with Speare on the topic of laundry chemistry quickly and quite deliberately became a

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[75] Ibid.

[76] "R.K. Duncan to E. Ray Speare December 5, 1906" in Carnegie Mellon University Archives, Mellon Institute Documents Box 209, ff7664.

model for academic-industrial collaboration. Over the next three years, another 16 fellowships were added to the program at the University of Kansas. They included (in order of creation); alfalfa, salt-rising bread, casein,[77] oil, enamel, glass, cement, varnish, borax, adrenaline, vegetable ivory,[78] gilsonite,[79] fats, leather and copper.

For Duncan, the industrial fellowship program that he piloted was a solution to a very practical need that could be addressed by a productive combination of people and knowledge. He also viewed the industrial fellowship program as a way for young scientists to begin to build successful careers. He said, "It seems clear that these problems can be best answered by combining the practical knowledge and large facilities of the factory with the new and special knowledge of the universities, and by making this combination through young men who will find therein success and opportunity." Through the industrial fellowship program, Duncan intended young scientists to transform, as he put it in *The Chemistry of Commerce*, the "vast body of knowledge called Science and to make it subserve the practical needs of the human race."[80] For Duncan, the idea of academic-industrial cooperation was timely and necessary because problems that could be handled in the factory through rule of thumb methods were now a thing of the past. He asserted, "problems having obvious and apparent answers have all been solved."[81] Despite the dearth of unsolved problems with what he called "obvious solutions" there was still much work to be done for the academic laboratory.

[77] phosphoprotein commonly found in milk
[78] hard white endosperm of seeds from palm trees that resembles ivory
[79] a naturally occurring hydrocarbon resin found in northeastern Utah
[80] Duncan, *Chemistry of Commerce*, 255-6
[81] Duncan, *Chemistry of Commerce*, 247

THE "EMBRYONIC PHASE" OF THE MELLON INSTITUTE

Duncan described the landscape of potential for applied science -

> "Everywhere, throughout America, wherever there is the smoke of a factory chimney, there are unsolved, exasperating, vitally important manufacturing problems – problems in glass, porcelain, starch, tanning, paints, drugs, metals, iron, oil, metallurgical products – problems wherever man deals with substance."[82]

Perhaps it was this sense of the omnipresence of industrial problems that unified American business under an umbrella of practical science expressed through a popularly accessible narrative that inspired the Mellon brothers, Andrew and Richard, to support the creation of the Mellon Institute for Industrial Research in Pittsburgh, with Duncan as its first director. Indeed, in 1910 when Duncan was invited by the Chancellor of the University of Pittsburgh to discuss his fellowship system in a tentative and confidential meeting in Pittsburgh, it was because Andrew Mellon had read Duncan's most recent book "with interest." Mellon recalled,

> "the part which particularly enlisted my attention was the last chapter in which Dr. Duncan described his plan for industrial fellowships, by means of which industry could utilize the services of qualified scientists to solve its problems...After pointing out the confusion and waste in manufacturing, most of it chemical rather than mechanical, he went on to say that, with larger combinations of capital and a new generation of business men becoming aware of the possibilities of the new knowledge, improvements were coming and would continue to come in industry as the aid of science was invoked to solve the problems constantly arising."[83]

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[82] Duncan, *Chemistry of Commerce*, 255

[83] AW Mellon's speech at the dedication of the building delivered in Carnegie Music Hall May 6 1937 – reprinted in the *Mellon Institute News* vol XXXII no 5A (1968) in Carnegie Mellon University Archives, Mellon Institute Documents

"The manner in which it came about was quite unpremeditated, as those things often are. Strange as it may seem, it all goes back to a school of languages and a quite innocent desire on my part to speak French fluently enough to travel abroad in comfort – a desire I may add, which remains unsatisfied to this day. At any rate, I called the school for help and they sent a young Frenchman to my house in the evenings during the summer of 1909. He was a very enthusiastic young man and one night he brought a letter from his father in France who had made a chemical discovery, as he thought, and wanted it tested by some industry in a position to utilize the discovery commercially.

Only one month after this meeting at Chancellor McCormick's home in 1910, Duncan moved with his wife and daughter to Pittsburgh where the Mellon family funded him on a trial basis to develop the fellowship model in this new location. Originally titled the Department of Industrial Research at the University of Pittsburgh, a wooden building was constructed to house both laboratory space and offices. By 1913 the fellowship contracts begun at the University of Kansas were closed and the entire fellowship system was transferred to Pittsburgh. The first permanent brick and stone building would now replace the "small experimental wooden building," and would bear the name of its benefactors, as the Mellon Institute of Specific Industries. Duncan himself would not live to see it to completion however. He passed away from a long-standing gastric ulcer while the building was still under construction. [84] Although Duncan himself died shortly after his appointment, the industrial fellowship model that he brought from Kansas to Pittsburgh, then an epicenter of American industry and wealth, would nevertheless survive and flourish.

I gave the letter to the general manager of the Gulf Oil Co., who reported a few days later that the supposed discovery was not of practical value, and to prove it, gave me a book called "The Chemistry of Commerce" by Robert Kennedy Duncan, a professor of chemistry at the University of Kansas. I read the book with interest, but the part which particularly enlisted my attention was the last chapter in which Dr. Duncan described his plan for industrial fellowships, by means of which industry could utilize the services of qualified scientists to solve its problems, in much the same way as is being done here today. After pointing out the confusion and waste in manufacturing, most of it chemical rather than mechanical, he went on to say that, with larger combinations of capital and a new generation of business men becoming aware of the possibilities of the new knowledge, improvements were coming and would continue to come in industry as the aid of science was invoked to solve the problems constantly arising."

[84] "Lois Whittle to Rena Zeffer April 13, 1962" in Carnegie Mellon University Archives, Mellon Institute Documents Box 198, ff7114.

THE FELLOWSHIP AGREEMENT

In order to understand the way that the Mellon Institute functioned to promote academic-industrial cooperation, it is important to examine the mechanism by which these two interests were brought together. Earlier in this chapter, I analyzed the body of correspondence that led to the formation of the first industrial fellowship at the University of Kansas. In this section, I focus on the fellowship agreements at the Mellon Institute as both a window into the practice of academic industrial cooperation, and as a material artifact in their own right, which embodies the organizational innovation developed in this institutional context to promote industrial research. These living documents served as a tangible convening point for the interests of science and business that were brought into productive balance anew through each particular research project. They help us to understand the production of knowledge at the then-developing interface between academic and industrial research. They also delineate the organizational systems that kept such complex partnerships productive and sufficiently legible to their multiple constituencies.

To access the Mellon Institute fellowship agreements (or any other Mellon Institute records) today, you must order them at least week in advance at the Carnegie Mellon University Archives. They are delivered from the Iron Mountain off-site storage facility in cardboard file-boxes secured with fused plastic binding tape. Unlike the familiar ordered line of file folders that often greets an archival researcher, the fellowship agreements are stacked on end, packed together like an array of partially flattened scrolls. This series of dense beige spirals segmented from each other by the light blue covers that surround each bundle face you in a cryptic mass of coiled paperwork. As a contemporary researcher with the task of understanding the daily inner workings of the Mellon Institute for Industrial Research nearly a century later through the documents that remain, the sight of these fellowship agreements can be a bit bewildering.

However, when the Mellon Institute was in operation, what is now a daunting array of agreement documents were part of a well known and highly sought after organizational system. Indeed, "any report or letter [could] be produced in a matter of minutes, no matter how many years ago it was written." So said Director Weidlein in 1956 as he marveled at the immediacy with which he was given a document from 1915.[85] This particular organizational innovation was the brainchild of Lois Whittle, who began as Secretary to the Director in 1910, when the headquarters were in the attic of Duncan's home in Pittsburgh. During this modest "embryonic phase" [86] of what was to become the Mellon Institute, Duncan and Whittle were its only employees in Pittsburgh. At this time the research projects were still being conducted at University of Kansas. Whittle continued to refine her system throughout her 45-year career at the Mellon Institute, later serving as its General Office Manager. Whittle recalled first being faced with what she described as "a huge box of Kansas records in the middle of [Duncan's] attic floor."[87] Duncan's only direction at the time - "a card Miss Whittle, a card for everything!" - though strict, also came with as she put it, "immense latitude."

The Mellon Institute would move from Duncan's attic to a series of temporary wooden buildings, to a more permanent brick structure in 1915, and then finally to the iconic "New Building" in 1937. With each year the research activity grew, challenging

[85] *Mellon Institute News* Vol XIX no. 22 Thursday, March 1, 1956, in Carnegie Mellon University Archives, Mellon Institute Documents, Box 198 ff7114
[86] "Lois Whittle to Rena Zeffer April 13, 1962"
[87] Ibid.

both the organizational and physical limits of the staff and facilities. Managing the logistics of a multiyear fellowship, its funds, sponsoring company or group, research fellows, equipment needs, and their findings was a complex task. In fact Whittle, in response to numerous requests from outside the Institute, published an article in the journal *Industrial and Engineering Chemistry* in 1928 making her system available to other laboratories. Each new donor, whether an individual, firm, or trade association, "upon becoming a member of the Institute fellowship family" was given a unique file number which did not change regardless of the number of fellowships associated with that particular donor. This number served as a "permanent guide to all the activities of a fellowship" including correspondence, reports, and associated visual materials such as slides or blueprints. The reports associated with a particular donor were considered a "unit" and were kept isolated from the other types of materials. Reports themselves were classified by time period; weekly, monthly, "special (written as necessity arises)," annual, and monograph for the final summary. The fellow was responsible for selecting keyword subjects to aid in filing and placing these at the top of each page. This was often later cross-referenced by the office examiner. "A comprehensive guide to the records of each and every fellowship" was kept in the form of a "general card index" accessible only to the executive staff of the Institute. Whittle explained that with the multiple fields of file number, fellowship number, date, author, and classification, "the finding of a report becomes a simple matter." The cards themselves were placed first in alphabetical order and then organized by subject numerically according to the donor number. The benefit of this arrangement was that it placed "all work on a given problem together under the same fellowship," and "as there is not much typewritten matter to be entered on these cards, the cross-indexing of a report involves little labor."

Whittle offered that her system was particularly effective "in making possible the recorded investigations of minor points tangent to a major problem and, in general, in guarding against those hazards which are to be expected through lapse of time, changes in personnel, etc."[88]

This pre-digital system of indexing, multicolored file cards with typed and handwritten fields, progress reports and financial records organized by Whittle and her staff, help us to understand the fellowship agreement as a living document. The fellowship agreement itself played several roles simultaneously within the industrial fellowship mechanism at the Mellon Institute. A template version of the agreement appeared in the annual reports, which were published as articles in two well-known scholarly journals, *Science* and the *Journal of Industrial Chemistry.* The template provided a standardized format for all industrialists, companies or manufacturing associations seeking a relationship with the Mellon Institute. Regulations about intellectual property and publications were clearly spelled out leaving little room for ambiguity. The only fields that were left open to be filled out specifically with each new agreement included the name of the parties involved, relevant dates, subject of the fellowship and amount for the maximum cash bonus awarded to the Fellow.

This is notable for several reasons. It shows that the fellowship agreement was intended to be: 1) both standardized and transparent; and 2) not solely an internal legal document, but also a significant aspect of the public face of the Institute. The Institute sent a clear message, by placing the fellowship agreement in this widely read scientific journal, that the agreement was a critical piece of the work that was happening at the Mellon Institute, along with its projects, fellows, budgets, and contributions to

[88] Lois Whittle "Indexing Research Reports" *Industrial and Engineering Chemistry* Vol 6 No 16 (Aug 20, 1928) 9.

industrial science. In some cases, the text of the agreement occupied just as much space in the journal as the report itself. Of course, this was also an excellent forum for exposing potential sponsors, or researchers for that matter, to the mechanism that formed the basis of this work, a mechanism that bridged the academy and industry.

"However important to industry the institute's work may be, a still more valuable by-product is the training given to those who have taken their advanced degrees and who in time become capable of directing research. This is of great importance, as we always lack a sufficient number of real leaders," reflected Harrison E. Howe, editor of *Industrial and Engineering Chemistry,* upon the dedication of the "New Building" of the Mellon Institute in 1937. Indeed, the fellowship agreement, which formalized the relationship between academic science and industry on paper, relied upon at least one fellow to do the actual work of science. At the Mellon Institute, these fellows were mostly PhD or master's level scientists. In some cases the larger projects also included bachelor's level scientists who could earn their graduate degrees through affiliation with the University of Pittsburgh. As described earlier in this chapter, Duncan and Speare ambitiously constructed the role of the first industrial fellow at the University of Kansas who would work in the laundry fellowship. This first fellow in the Kansas system, Fred Faragher earned his doctorate through the laundry fellowship work and later went on to serve on the Institute staff in Pittsburgh and continued his career in the field of petroleum. The establishment of the laundering fellowship led to the creation of the American Institute of Laundering, whose president, Dr. George H. Johnson, was also a former industrial fellow.[89]

[89] ER Weidlein's Address at the celebration of the fiftieth anniversary of the Mellon Institute. Harold Klug ed. *Science and Human Progress* (Pittsburgh: Mellon Institute,1963)

Indeed, it was Duncan's intention for the industrial fellowships not only to produce new useful knowledge, but also to help launch the careers of young scientists. Perhaps the story of another young man from Kansas, who began his career under the supervision of Duncan "walking around the inside of a whale," and who would ultimately spend a 45 year career leading the Mellon Institute, might not be a representative story of the path of the typical industrial fellow.[90] However, it does give us a window into all aspects of the industrial research program through the life of a single individual. That man was Edward R. Weidlein, who served as director from 1927 to 1956.

"Boy, I have a challenging new problem for you," Weidlein recalled Duncan catching his attention yet again, with his characteristic ambitious magnetism. Weidlein had just finished a project on camphor, and Duncan was already recruiting him for another project. He had just received a thousand dollars to study ductless glands of whales in an effort to possibly establish a new medical industry in Labrador for Sir Wilfred Grenfel. Despite the fact that neither Duncan nor Weidlein had any background in this area, they took the project on and began their work in the library.[91] They collaborated with physiologists at Johns Hopkins, Columbia and the University of Toronto, and before long Weidlein was off to Newfoundland and Labrador. He would return with over one hundred pounds each of supra-renal glands and thyroids, as well as other glands, which would yield a very pure form of adrenaline.[92] Although the fellowship paid him for a year and included travel expenses, Weidlein did have to "draw

[90] Lois Whittle's impressions of Duncan on their first meeting in September 1910 - printed in Mellon Institute News vol XXXII no 5A Nov. 1 1968 in Carnegie Mellon University Archives, Mellon Institute Documents Box 198, ff7114.
[91] Harold Klug ed. *Science and Human Progress* (Pittsburgh: Mellon Institute, 1963) 20.
[92] Duncan's speech "Industrial Fellowships" delivered at the residence of Chancellor McCormick October 17 1910, in Carnegie Mellon University Archives, Mellon Institute Documents 205 ff7495.

on [his] own resources," a circumstance that Weidlein attributed to Duncan's "drive for achievement."[93] The extraction of ductless glands from deep-sea mammals in Canada may seem an odd endeavor. However this example highlights both the spirit of inquiry to engage with unfamiliar topics and the subsequent diversity of work acquired by Duncan and undertaken by the fellows with great ambition and intensity.

Although Duncan had moved to Pittsburgh in 1910, he initially continued to manage the projects in Kansas as well. In 1912, he decided to focus all of his efforts in Pittsburgh and recommended that Weidlein take over the Kansas operations "at the ripe old age of twenty-four." Dismayed that this "was too fast an advancement for even [Weidlein's] most loyal members on the faculty to accept," Duncan moved the entire department to Pittsburgh.[94]

Following Duncan's untimely death in 1914, Raymond Bacon who had previously served as associate director, became director with William Hamor now serving as associate director. Weidlein became assistant director of the Mellon Institute in 1916 at the age of 28. Shortly after this shift in leadership, both Bacon and Hamor went to Europe to serve in the war effort as members of the Chemical Service of the National Army. Weidlein maintained the operations in their absence, and so news often crossed the Atlantic between Hamor and Weidlein.[95]

Originally the Mellons had planned to fund the Institute for a period of five years. Yet they extended their support to 1921 due to the wartime considerations. Although the Institute was technically a part of the University of Pittsburgh, it enjoyed

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[93] Klug ed. 20.
[94] Klug ed. 21.
[95] See wartime correspondence between Hamor and Weidlein in Carnegie Mellon University Archives, Mellon Institute Documents Box 205 ff7509

a "very loose operating arrangement."[96] In 1921 the Mellons gave the Institute formally to the University of Pittsburgh, though as Weidlein reflected, Chancellor Bowman "never quite accepted the Institute as a real gift and we continued to operate, with his support, but very much on our own." [97] In that same year, while still only acting director, Weidlein made the Institute self-supporting by placing a twenty percent overhead charge on all of the fellowships. The Mellon Institute continued to grow and in 1927 was granted a separate charter by the state of Pennsylvania complete with a separate board of trustees and management team. Weidlein became director in his own right at this time, and president when the title changed in 1950. He remained in this role until his retirement in 1956 and was well known as both a scientist and manager. At a dinner in 1967 given in his honor, Paul Mellon, Andrew Mellon's son, told the audience that Mr. Weidlein had extracted copper from low-grade ore and extracted a cure for epilepsy from something else. "But Weidlein was most successful at extracting greenbacks from the Mellons." [98]

As the head of the Mellon Institute, Weidlein traveled abroad on two major European tours, following both World Wars, in 1927 and again in1956. These international trips help to contextualize the impact of the Mellon Institute and the practice of academic-industrial cooperation beyond the regional or even national context, showing it to have been part of a larger global phenomenon. In 1927 Weidlein wrote from Frankfurt to his colleagues in Pittsburgh, "Hurrah! This is the place for me." Although he went on to praise the coffee and cigars, other aspects of German society would surely have made him feel quite at home as well, especially the structure

[96] Klug ed. 21.
[97] Klug ed. 21.
[98] http://www.nytimes.com/1983/08/19/obituaries/er-weidlein-ex-director-of-mellon-research-institute.html accessed April 7, 2014

of research institutes that closely linked the academic laboratory to the industrial sector.

It might even seem ironic that Weidlein would be touring Germany to promote the Mellon Institute's brand of industrial cooperative research as an American export product. After all, the first lab that combined teaching and research was founded in Gissen in 1826 by the chemist Justus Liebig.[99] Germany and Switzerland were already especially well known as leaders in the chemical field before the founding of the Mellon Institute. Indeed, the industrial fellowship program in place at the Mellon Institute was only a bit over a decade old at the time of Weidlein's first European tour. This program, which was gaining notoriety at the time as an innovation in the coordination of American science and industry, shared striking similarities with German models established at the end of the previous century. In fact, the industrial fellowship system that gave rise to the Mellon Institute was inspired by Duncan's own experiences aboard beginning in 1901 in the laboratory of Pierre and Marie Curie in Paris. He returned to Europe in the summers of 1903, 1905 and 1906 to collect material, which would inform his books and articles in numerous ways. He was most influenced by the "most efficiently working mechanism" between universities, industries, banks and transportation companies as practiced in Germany.[100]

Weildlen, like Duncan twenty years earlier, was also collecting ideas to bring back to the United States. In 1927 he visited England, Germany, Switzerland, Italy and France, touring a mix of educational institutions, research laboratories and chemical works. He described the general science building at the University of Bristol in England as one that "would be ideal as a new Mellon Institute. It is the most complete

[99] Hartmut Lehmann ed. *The German Influences on Education in the United States to 1917*. German Historical Institute and Cambridge University Press 1995.
[100] "R.K. Duncan to E Ray Speare November 10, 1906"

type of building and is regarded as the best single piece of architecture in Europe." In contrast the University of Brimingham and Manchester were "just ordinary" but staffed by "some good men" and he felt that the results of their conferences together would prove useful in the coming years. The Kansas fellowship system that set the groundwork for the Mellon Institute had its origins in textile work with the laundry fellowship. Yet after visiting the Textile Institute, Shirley Institute and the Bleachers Association Research laboratories in England, Weidlein wrote to his colleagues "I am thoroughly convinced that we do not know anything about textiles." He was happy to report, however, that he had "obtained a lot of valuable information which will benefit all of our textile research" and though he couldn't elaborate on the details in this handwritten letter on small hotel stationery, he assured his colleagues that he felt "greatly encouraged" by his warm reception and meetings with prominent chemists.[101] While Weidlein was travelling he exchanged letters with Mellon Institute assistant director, George D. Beal, who was doing preliminary work on a project on waterproofing fabrics. Beal sent a detailed list of patent abstracts including technologies from the US, Canada, France, and Germany, demonstrating that even in early stages of research they took an international perspective.

Weidlein's itinerary from 1927 was published in the already well -established science journal, *Nature*, and his trip was also announced in chemistry-focused journals such as *Chemical Markets* and *Industry and Engineering*, among others. The scale and scope of Weidlein's 1955 tour was more extensive than his earlier trip, reflecting not only the growth in the Mellon Institute but also the role of the United States after the Second World War. On this trip, Weidlein was traveling "at the request of the Federal

[101] E.R. Weidlein to Bill, Tilly, George, Harry and Miss Whittle September 14, 1927 Windermere England "Weidlein Correspondence 1925-29" in Carnegie Mellon University Archives, Mellon Institute Records, Box 196 ff7108.

Government's Foreign Operations Administration, in cooperation with the European Productivity Agency."[102] He led research seminars in France, Belgium, Norway, Italy, Austria and Turkey in order to "acquaint small and medium-sized industrial firms of those countries with the importance of applied science research and with the advantages to be derived therefrom." These meetings located in various cities typically lasted for three days each and were facilitated through simultaneous translations via headphones and attended by between forty and fifty invited industrialists.[103]

As we reflect now on these highly visible international tours, it is worth thinking about them as not only a unidirectional act of American technological diplomacy, but also as critical opportunities to learn from European colleagues and their institutions and to form new partnerships. These tours, and associated correspondence, help us think about two kinds of bridging; 1) between nations; and 2) and between the academy and industry. They help us to compare the state of the art in academic-industrial cooperation and research and development on either side of the Atlantic through the eyes of an American leader in this field at the time. Considering that R&D in this period is often thought of in terms of regional or national development, it is especially important to consider how people and ideas could influence each other across international boundaries.

Finally, by bringing the Mellon Institute into an international context, especially as a representative of American innovation in this field, I underscore the now easy to underestimate importance placed on this Institute and its role at the time. The letters bring international aspects to the forefront of an often nationally-bounded

[102] "Weidlein Foreign Tour" 1955 in Carnegie Mellon University Archives, Mellon Institute Records, Box 209 ff7652.
[103] *Mellon Institute News* Vol XVIII No 45 (Thursday August 11, 1955) , and "Weidlein Foreign Tour 1955" in Carnegie Mellon University Archives, Mellon Institute Records, Box 209 ff7652.

narrative. The story of innovation as told through patents, products, chemical processes, and the new consumer opportunities that they created is a well-known piece of the American R&D ecosystem in which the Mellon Institute flourished. However, in this chapter I have shown that these oft-heralded products were not the only contributions of this non-profit research enterprise. Their organizational structure, built around the industrial fellowship agreement at its core, was itself an innovation. In the midst of the "cataclysm of the Great War," when interest in the power of applied science to shape the outcomes of nations and their economies was beginning to take hold on a broader scale, the young acting director Weidlein wrote, in his report to *Science,*

> "With this idea in mind, institutions of learning and industries in this country, but more especially abroad, are investigating and studying methods to bring about cooperation between science and industry. The Mellon Institute is proud that, while very young, it has been a pioneer in the field. Its principal claim to distinction, apart from its contributions to specific industries, is based on the service it has been able to render to other institutions in demonstrating the practicability of a system which brings together science and industry for the development of a future and more gracious civilization."[104]

Although this statement was made a decade before the iconic "New Building" was erected, and half a century before the Mellon Institute, having run its course as an independent research institute in service of industry, would join with Carnegie Tech to form Carnegie Mellon University, this statement about the Institute's contributions remains valid. It is through this example of the development of the industrial fellowship program, its test bed in Kansas, and subsequent growth into a major research center in Pittsburgh that we can understand that innovation, a process built with ideas and networks, was deliberately coordinated.

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[104] Weidlein acting director – end of the annual report published in *Science* Vol XXLII no 1219 (1918) 450.

The case of the industrial fellowship system employed at the Mellon Institute is not just a story about the development of organizational structures, policy, and intellectual property, though all of these are vital pieces of the whole. Even more importantly, it is part of a larger narrative that also asks – what is progress? How is it envisioned and enacted during this particular formative time in American industrial development? In the chapter that follows, I will continue to engage these enduring questions about innovation, useful knowledge and industrial development through the lens of science and engineering education.

CHAPTER 3
"A TECHNOLOGICAL EDUCATION:" ENTREPRENEURIAL VISION AND EDUCATIONAL STRATEGY AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

"In Short, the Massachusetts Institute of Technology would become the greatest consulting body in the world..."[105] envisioned MIT's president Richard C. Maclaurin in 1920 with the launch of the Technology Plan. This initiative formalized MIT's relationship with industrial partners by offering a subscription model for access to research and other campus resources. Although research with industrial partners had existed at MIT since the 1880s, the arrangements had been maintained by individual faculty members or departments and operated exclusively on an *ad hoc* basis. The creation of the Technology Plan, or Tech Plan as it was often called, was the first step in a series of programs that would transform industrial activity already present on campus as well as create new opportunities for increased industrial collaboration through a centralized mechanism. During the 1920s and 30s, MIT's leaders engaged in definition-setting and boundary-making for their educational programs, along with the increased formalization of research initiatives, creating a model that was flexible enough to take advantage of funding and industrial trends yet without sacrificing any of MIT's academic prestige.

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[105] "The Technology Plan" *The Technology Review* xxii (1920): 52-61.

The preceding chapter focused on the Mellon Institute for Industrial Research, mainly a post-graduate, non-degree-granting, not-for-profit institute that was "allied cooperatively" with the University of Pittsburgh. Here the educational component of the industrial fellowship system for young scientists with advanced degrees was linked to specific research projects rather than to prescribed courses of study. The Mellon Institute for Industrial Research had been created with the explicit mission of "promoting the increase of useful knowledge" through the development of industrial research.[106] This chapter looks instead to the Massachusetts Institute of Technology (MIT) in order to explore the development of academic-industrial science within an institutional environment characterized by both a formal educational program as well as an increasingly strong research focus. In this case, the growing emphasis on industrially relevant science served to highlight already present tensions surrounding disciplinary boundaries and status between basic and applied sciences, and engineering. I argue that the emergence of industrial science as a disruptive field also helped to push forward a new model for science and engineering education that had as its aim the achievement of a balance between fundamental science training and its potential practical applications. Rather than being tied to a particular industry, the combined education and research strategy employed at MIT would stay adaptable, thereby enduring in the face of changing funding and industrial climates.

MIT is often heralded as an innovator in successfully linking research and education with industrial leadership. Henry Etzkowitz, a scholar of science policy, calls this mode of operation "entrepreneurial science,"[107] while historian of science and

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[106] "RK Duncan to University of Pittsburgh Office of the President October 15, 1910" in Carnegie Mellon University Archives, Mellon Institute Documents, Box 209 ff7664.
[107] Henry Etzkowitz *MIT and the Rise of Entrepreneurial Science*, Routledge 2002.

technology Christophe Lécuyer thinks of it as the creation of a "permeable university."[108] Founded in 1861, MIT, or Boston Tech, as it was often called due to its original location in the Back Bay, began as an undergraduate-focused polytechnic institution. By 1916, when it moved across the Charles River to the Cambridge campus where it remains today, MIT was already on its way to shaping both the trajectory of science and engineering education in the United States, and the role of an academic institution as a strategic actor within the greater corporate innovation landscape.

This chapter addresses two particular aspects of the entrepreneurial strategy employed by MIT's leaders in the early 20th century: the establishment of an ambitious and clear initiative to engage with companies from a wide variety of sectors; and the creation of a flexible educational program that combined academic rigor with practical applications. I trace these combined strategies in terms of both the narrative strategy employed by MIT's leaders, as well as an analysis of how their initiatives took shape in practice, as demonstrated through the functions of offices, laboratories and educational programs. Archival sources include leadership speeches, correspondence, internal and externally circulating published reports, and articles in academic and trade journals. The development of a flexible educational program that sought to differentiate the MIT model of engineering education from both ordinary vocational training and traditional elite science was first articulated through the public addresses of MIT's presidents during the early 20th century, Richard C. Maclaurin, Samuel S. Stratton and Karl T. Compton.

This entrepreneurial shift is not without critique by contemporary scholars. In *Ivy and Industry (2003)*, Christopher Newfield, skeptical of the influence of business on the academy, characterized the modern research university system as a bureaucracy of its own self-entrenchment occupying an internally conflicted space between creating intellectual freedom from the entanglements of the corporate capitalist world and aspiration to it in terms of management and efficiency metrics.

[108] Christophe Lecuyer, "Academic Science and Technology in the Service of Industry: MIT Creates a "Permeable" Engineering School," *The American Economic Review*, 88(1995):28-33.

Similar to the efforts undertaken by the leaders of the Mellon Institute to build legitimacy for industrial science, as illustrated in the preceding chapter, MIT's leaders were also engaged in legitimacy making for their own emerging model of science and engineering education. This model, described by the Institute's motto "*mens et manus*," or "mind and hand," combined both the theoretical science components that would have been familiar to any academic scientist at the time, with laboratory or other hands-on experience. The case of the cross-disciplinary research laboratory and program in textiles serves to illustrate how these plans to create elite, yet industrially relevant, research and curricula functioned in practice despite the several challenges that it faced. Through a review of the Tech Plan, and the structured relationships that it created between the Institute and industrial partners, most importantly embodied in the Office for Industrial Cooperation, I bring the perspective of administrative and organizational practice into focus.

THE TECH PLAN: A STRATEGY AND STRUCTURE FOR INDUSTRIAL ENGAGEMENT

Although research work with industrial partners began in the early 1880s on an *ad hoc* or individual faculty basis, an explicit, centralized scheme for incorporating industrial work into MIT's core functions was only announced in 1920. The Tech Plan, boldly set forth by Richard C. Maclaurin shortly before his untimely death while serving as MIT's seventh president, envisioned a powerful working relationship between the Institute and would-be industrial partners. It was designed as a fund-raising tool for the Technology Educational Endowment Fund, to meet a four million dollar matching grant from George W. Eastman, founder of the photography company

Eastman Kodak.[109] The Tech Plan claimed to be "the first complete scheme ever worked out by a technical institution for co-operation between a school of pure and applied science and the industries depending upon this science."[110] Within this system, a Division of Industrial Cooperation would be created which would act as a centralized body to connect companies with MIT resources. This was meant to replace the scattered and informal arrangements between individuals and companies that had been common practice prior to that time. Through the payment of an annual "retainer," a corporation could gain access to information and expertise in the form of consultation, laboratory research and library privileges. At the time of its public launch via publication in *Technology Review* in 1920, the Tech Plan had a roster of nearly two hundred companies of various sizes representing a wide range of manufacturing and material processing functions.

The Tech Plan, as described in President Maclaurin's address delivered at the Alumni Banquet in 1920, was "a natural outgrowth of [MIT's founder William Barton] Rogers' conception of the Institute"[111] and (quoting Rogers) "a 'suitable means' whereby the Institute can aid 'the advancement, development and practical application of science in connection with arts, manufactures and commerce.'" [112] Through this Plan, Maclaurin hoped, "In Short, the Massachusetts Institute of Technology would become the greatest consulting body in the world."[113] Despite the strong industrial component, it was not meant to detract from the primary educational mission of the Institute.

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[109] The charge was to raise three million dollars before December 31, 1919, and reach four million before January 10. However, President Maclaurin died on January 15, 1920 before this was completed. *MIT Reports to the President*, 1919, p. 10-14. available at http://libraries.mit.edu/archives

[110] "The Technology Plan" *The Technology Review* xxii (1920): 52-61.

[111] William Barton Rogers was the founder of MIT.

[112] President Maclaurin's was absent due to illness, the address was delivered by Professor Sedgwick. "Address of President Maclaurin at Alumni Banquet Boston, January 10, 1920" in MIT Reports to the President, 1919, 13-14, available at http://libraries.mit.edu/archives

[113] "The Technology Plan" *The Technology Review* xxii (1920): 52-61.

However, the appropriate balance between these new engagements and the educational mission already in place was an ever-shifting and often controversial element, which was expressed through often heated faculty debates about the relative merits of applied versus fundamental research within the academy.

"Technology itself is much more than a school," Maclaurin asserted, thus effectively widening the concept of educational mission to include the entire ecosystem of the Institute. [114] Although MIT was certainly not the only institution to have incorporated the word *technology* in its title, at this time "Technology" was still used as a recognizable shorthand way to refer to the school. For Maclaurin, the creation of "the right kind of organization" to aid industrial cooperation with both information and personnel was a natural imperative. "A mere school might not be able to do this, but an institution conceived so broadly as Technology is well adapted for this great end."[115] However, the particular execution of the Tech Plan and subsequent integration of industrially relevant curriculum and research components took a variety of forms within research and degree programs.

ENTREPRENEURIAL LABORATORY MANAGEMENT: THE DIVISION OF INDUSTRIAL COOPERATION & RESEARCH LABORATORY FOR APPLIED CHEMISTRY

Even within this relatively small educational organization,[116] which functioned in the physically conjoined "main group" of buildings designed by Bosworth to foster connectivity across the new 1916 campus, there was still considerable diversity of

[114] MIT was commonly shorthanded as "Technology" at this time
[115] "The Technology Plan" *The Technology Review* xxii (1920): 52-61.
[116] For example, in 1916 there were 1,957 students (1,919 undergraduates and 38 graduate students) http://web.mit.edu/registrar/stats/mobile/all-time/enrollment.html as well as approximately 300 instructional staff members including professors and lecturers and assistants. *MIT Reports to the President* 1916

experience and outlook when it came to interpreting the academy's role in relation to industry. The development of research and education in the chemical fields during the early 20th century at MIT highlights larger themes in both educational development and strategic collaboration with industrial partners. The first masters and doctorate degrees were both awarded in chemistry, in 1886 and 1907 respectively.[117] During the 1910s, an especially formative period in the history of MIT,[118] three distinct faculty groups, each containing an influential chemist (Arthur Noyes, William Walker and Henry Talbot), vied for influence over the trajectory of industrial service at the Institute. Each of these three chemists had jurisdiction over organizational structures that were closely tied to their educational and industrial agendas. Noyes founded the Research Laboratory of Physical Chemistry in 1903, which led to the development of graduate science education at MIT and prepared many physical chemists for industrial careers. Noyes took a keen interest in the newly established corporate laboratories at DuPont and General Electric and saw in them career paths well-suited for MIT graduates. Five years later, Walker, a chemical engineer, established the Research Laboratory of Applied Chemistry (RLAC). Along with Dugald Jackson, then the chair of the Department of Electrical Engineering, Walker and his faculty allies aimed to move away from the idea of engineering graduates as skilled technicians for industrial laboratories and toward an emerging concept that an engineering education might also prepare future corporate leaders.[119] Although Talbot, the chair of the Department of Chemistry, was in favor of formalized research programs with industrial aims, he and

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[117] http://libraries.mit.edu/archives/timeline/

[118] During this decade MIT moved to its newly designed Cambridge campus and went through a period of expansion.

[119] Dugald Jackson's role as an institutional entrepreneur is discussed in W. Bernard Carlson's "Academic Entrepreneurship and Engineering Education: Dugald C. Jackson and the MIT-GE Cooperative Engineering Course, 1907-1932" *Technology and Culture*, Vol. 29, No. 3 (July 1998) 536-567.

his faculty allies were more concerned with "keeping in touch with engineering practice and finding jobs for graduates" than pushing engineers into corporate leadership roles.[120]

The case of RLAC, which operated from 1909 to 1934, serves to illustrate the initial successes of Walker's model of entrepreneurial laboratory management as well as the organizational challenges within the institutional ecosystem at MIT. In many ways, the functioning of RLAC exemplified the idea of MIT as a "consulting body," even before Maclaurin described it as such in the 1920 Tech Plan. Projects could include not only chemical testing, but also market studies associated with the particular materials of study. During 1910 and 1911 RLAC researchers had a variety of projects such as testing insulating material for General Electric, wool grease for Arlington Mills, palm oil for American Sheet and Tin Plate Co, and commercial glycerine processing for DuPont de Nemours Powder Co. The bound reports, which are available in the MIT Archives, chronicle the development of each research project including interim updates sent to the industrial partner as well as the final summary. They include explanations of the chemical reactions of interest, backgrounds and summaries of the problems being addressed, diagrams of experimental apparatuses, and test results as well as discussion of the problems within a broader industrial context. The reports included discussions of work quite outside of activities that might be expected in a chemical laboratory. For example, a project that focused on uses for wool grease, a commercial byproduct of Arlington Mills, included not only testing of the material itself, but also interviews with local companies about their current use of greases and possible interest in wool grease. In a project about corrosion of wrought iron and steel pipes, chemical test results were

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[120] Noyes and Walker's "anything but compatible" approaches to chemical education are discussed at length by John W. Servos in "The Industrial Relations of Science: Chemical Engineering at MIT, 1900-1939" *Isis*, Vol 71, No. 4 (Dec 1980) 53-549.

presented along with interviews with practicing architects and building engineers about their experiences with these materials in the field.[121] These unusual activities demonstrate not only the diverse range of projects undertaken by the laboratory but also the full consulting approach taken by researchers to integrate market context with their chemical analysis.

RLAC operated from 1909 to 1934 with total revenues of $1,072,733 and expenditure of $1,147,668, a surprisingly modest shortfall.[122] Despite the difficult economic conditions for much of that period and the Lab's ineligibility for some types of grants due to the commercial nature of the research, RLAC still managed to nearly break even.[123] As a testing ground for industrial cooperation, it accomplished what the Tech Plan had set out as a model for supporting a wide variety of projects, including textile research. This laboratory also supported the educational mission of the Institute by providing a training ground for student theses with specific industrial applications.

Warren K. Lewis, the chair of the Chemical Engineering Department, described the particular intellectual and financial success of RLAC:

> "The Laboratory possessed certain extraordinarily important advantages. Because of its prestige, it was able to attract the strongest young graduates of the universities and technical schools of the country. Because these men were doing the work primarily for its training value, the laboratory paid them small salaries. Repeatedly, the laboratory held workers at one half or even one-third the salaries offered them in industry. Because of the quality of its staff and the atmosphere which contact with the Institute alone enable it to maintain, it was possible to

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[121] "MIT Research Lab of Applied Chemistry" 1910-1911, 1912-1913, in MIT Archives AC 465 Box 1. These two bound volumes are the only reports of this kind in the MIT archives.

[122] Some of these financial records including some sponsorships were not evident in MIT's President's and Treasurer's Reports because RLAC seemed to use a different fiscal cycle from the Institute at large. Foster, Leroy. "Sponsored Research at MIT, 1900-1968," unpublished manuscript, unpaginated, MIT Archives T171.M422.F67 1984 v1.

[123] A case in 1921 highlighted this particular difficulty "the RLAC was a commercial laboratory, supposed to acquire a considerable balance for Pro-Bono-Publico research. If the funds from the Cobot fund were to be used for these is work and the educational program the request would be approved. If the funds were for commercial or Pro-Bono-Publico work, the answer is No." in Foster, "Sponsored Research at MIT, 1900-1968."

> sustain an enthusiasm and offer inspiration which were major factors in its success. From this angle, no better method for training industrial research has been devised."[124]

The unique ability of the lab to retain highly skilled researchers, even at the relatively low wages it could offer in comparison to peers at industrial labs directly addresses the very concerns that had been raised by Stratton in the previous decade. In his speeches to industrial leaders, Stratton lamented the prevailing system of employment in which researchers, attracted by high wages, would inevitably move to industrial labs. He proposed that a close relationship between their companies and the academy could create not only researchers with skills more suited to their particular industries, but also alleviate some of the competition for these workers by employers which he viewed as destructive to both government and academic laboratories.[125] The creation of an intellectual environment at MIT that could educate and retain researchers engaged in research with industrial partners in this competitive labor market was yet another mark of success for RLAC.

Although the Division of Industrial Cooperation as created by the Technology Plan in 1920 had been envisioned as a centralized office for negotiating the relationship between the Institute and industrial partners, in practice these dealings had often remained within the jurisdiction of individual researchers and laboratories. This was the case with RLAC, which operated quite independently as a research center within the Institute. Soon after assuming the presidency Compton, made the evaluation and reinvigoration of the Division through the creation of more centralized industrial protocols one of his many organizational priorities. In 1932 he addressed the faculty,

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[124] W.K. Lewis c. 1931 quoted in, Foster, "Sponsored Research at MIT, 1900-1968."
[125] "Speeches 1923 – 24," in MIT Archives MC8, Box 8, Folder 94. "Speeches 1926-30" in MIT Archives, MC8, Box 9, Folder 95, 96.

saying "The entire object of the Division is to safeguard the Institute and to promote the most effective type of cooperation with industry. It is not intended to be officious or to interfere with individual initiative."[126] The very fact that Compton felt that he needed to present the Division in this way underscores a discrepancy, or at the very least a perception of one, between the intention of the Division as a central and efficient institutional office designed to mediate all industrial relationships and the limits of its operational oversight in practice.

The importance of creating a more unified MIT, both as an organization and as a brand, with regard to engagement with industrial partners is evident in the case of the RLAC. This laboratory, which was administratively housed within Chemical Engineering, may highlight a resounding achievement for the ideals of academia-industry collaboration as envisioned in the Tech Plan. Yet, it was this very success that also contributed to its ultimate dissolution in 1934. RLAC was far more autonomous in practice than had been envisioned by the Tech Plan. As a result, competition developed between this laboratory and the Division of Industrial Cooperation, thereby highlighting a weakness in the implementation of the Tech Plan itself. Although the desired type of research was being carried out and fruitful collaborations between industrial partners with RLAC were established, negotiations were not consistently cleared through the Division, creating not only confusion over contracts, billing, and reporting issues but also over the presentation of the Institute as a unified entity to industry.[127]

The nature of the archival materials that remain today chronicling the research sponsored by industrial partners during the 1920s and 30s highlight the tensions

[126] "Presentation of Work of the Division (of Industrial Cooperation) to the Faculty," in MIT Archives.
[127] Leroy Foster, "Sponsored Research at MIT 1900-1968" unpublished manuscript MIT Archives T171.M422.F67 1984 v1.

surrounding the multiple ways that industrial cooperation was practiced at MIT during this time. While retired from the directorship of the Division of Sponsored Research, F. Leroy Foster, compiled a manuscript on the history of this office, which also included the Division of Industrial Research.[128] Presented in two weighty bound volumes that may be accessed off the shelves of the MIT archives and special collections reading room, Foster's commentary is interspersed with copies of cost analysis charts, project summaries and lists of corporate partnerships. More a carefully constructed notebook than a finished report, perhaps it is the very patchwork nature of this document that is as telling about the Division's nature as the content itself. Foster included copies of extant Division and related institute reports and summarized many related resources available elsewhere in the MIT library system or departmental records. Yet, perhaps it is the omissions that are the most striking. Toward the middle of the document, somewhat hidden among report summaries, Foster briefly mentions that much of the material from the 1920s and 30s associated with the Chemical Engineering Department had been destroyed by Harold Carter "in accordance with instructions issued to him." In one sentence, Foster manages to breathe a sense of bureaucratic drama back into a set of documents, whose very nature is to obscure informal politics, personal charisma and conflict into characteristically dry summaries of 'facts' and figures. Without the records of the Chemical Engineering Department's industrial engagements, projects, and finances, one may only speculate as to the scope of involvement on the part of the department and individual faculty that inspired the official 'reorganization' of RLAC into an office designed to handle industrial relations across the Institute under a centralized and well monitored umbrella.

[128] Foster had also served as the director of the Division of Industrial Research. The office of Sponsored Research was created in 1955 and absorbed the function of the former Division of Industrial Research. A brief biography can be found here: http://newsoffice.mit.edu/2002/foster-0109 accessed May 16, 2014

The reorganization of the Division, a common shorthand for the Division of Industrial Cooperation (the name would later change to the Office of Sponsored Research) under Compton, along with the dissolution of RLAC became an important step in the administration's centralization of industrial connections. These measures served not only as a guide for what types of research and industrial relationships would be promoted by MIT, but also how they would be handled administratively in the future. The Division determined the terms of industrial contracts for all research agreements after 1932. These details required approval of the Division director, and commonly included publication rights for MIT research staff and other mechanisms to promote the sovereignty of the Institute.[129] The challenges associated with balancing academic and industrial research interests were also reflected in MIT's approach to education at this time, as described in the section that follows.

CREATING A MODEL FOR *TECHNOLOGICAL EDUCATION*

In 1931, MIT's president, Karl T. Compton described the Institute's model of education as "one which can produce leaders who will be able to handle the big and difficult problems of organization, production and new development."[130] He described this as:

> "In principle and generally in practice the Institute [Massachusetts Institute of Technology] has always aimed at technological rather than technical education, by which I mean education in fundamental principles and training in their application to important basic processes and problems as contrasted with training in manipulation or technique of routine, through skilled, technical operations. Though both types of training have their uses, we believe that that type which we try to emphasize is the one which can produce leaders who will be

[129] Lécuyer, "Patrons and a Plan," 74.
130 MIT Reports to the President, 1931, 10-13 available at http://libraries.mit.edu/archives

able to handle the big and difficult problems of organization, production and new development."[131]

For Compton, and MIT more broadly, the 1930s, were a time to formalize already existing operations, while remaining conscious of the need to be able to create opportunities for flexibility.

Historians have broadly characterized the rise of engineering education in the United States at the end of 19th century as the emergence of a "practical" education; that is, an education fashioned in the service of industrial innovation and of necessity liberated from the earlier model of an elite pursuit contained within 'ivory towers.' In his foundational work, *America By Design*, David Noble describes this period in engineering higher education as "the wedding of science to the useful arts,"[132] a practice driven strategically by the needs of corporate capitalists, who only stood to gain by the creation of a sustainable skilled workforce in collaboration with institutions of higher education.

In the particular case of MIT during this period, W. Bernard Carlson, a historian of science and technology, adds nuance to this simplified characterization of corporate agency to include "institution builders" from within the academy such as MIT's Dugald Jackson, chair of the Department of Electrical Engineering, who championed the cooperative course between MIT and General Electric from 1907 to 1932. Jackson helped to shape engineering education according to the priorities of his own academic institution through collaboration with industrial partners despite the initial reluctance of corporate leaders.[133] However, in this chapter, I am less concerned with attributing agency to either academic or corporate actors, than with understanding

131 MIT Reports to the President, 1931, 10-13 available at http://libraries.mit.edu/archives
[132] Noble.
[133] Carlson, 536-567.

how MIT leaders created an educational program that could differentiate the Institute from its peers in the science and engineering sector by combining academic rigor with opportunities for practical applications.

How then did leaders at institutions such as MIT design programs and funding structures to address a broad array of industries with the goal of producing, as Compton stated, "leaders who will be able to handle the big and difficult problems of organization, production and new development?"[134] For MIT, the approach included a combination of degree programs and laboratory research that aimed to balance basic science with industrially relevant problem solving. However, the balance between these particular components was still under development. The Textile Research Laboratory, which is discussed in more detail later in this chapter, highlights the way that broader Institute initiatives addressing industrially relevant work influenced teaching and research in practice.

By focusing on that specific case, I present the general model of education offered through the rhetoric of MIT's leaders, who emphasized flexibility and strong fundamental training in science within the context of industrial applications. In an effort to market the Tech Plan, Samuel Stratton, MIT's eighth president, delivered a series of speeches describing the merits of an MIT education to various industrial associations throughout the 1920s. He stated, "You can't teach a man to swim without water…You can teach a man to do research work, you can teach him chemistry and physics, but you want him to be familiar with the fundamental problems of your business…although it is not necessary for him to be a so-called practical man."[135] For

[134] *MIT Reports to the President,* 1931, 10-13
[135] "Speeches 1923 – 24"; "Speeches 1926-30."

Stratton, the 'water' needed for innovation, was a productive channel between industry and the academy.

He tried to make a case for a successful industrial system as one with a wide variety of individuals with specialized skill sets distributed among various roles within a coordinated system that included the academy, industry, and government. Stratton made an effort to present the resources of MIT as complementary to, and not in competition with, existing industrial groups. "One man may know how to attack a certain part of a problem while another know better how to solve another part; furthermore it is not necessary for him to bother too much with that part you know vastly better – he should know the scientific part of it, the chemistry and physics, while you can all help by working together."[136] In addition to the strong push for promoting greater comradeship in research between academic and industrial actors more broadly, this plea was also a pitch for companies to join the Technology Plan both philosophically and financially through sponsored collaboration.

This emphasis on characterizing the not only well prepared, but creative, engineer as a principle product of MIT continued with the Institute's next president, Karl T. Compton. When this prominent Princeton-trained physicist became MIT's president in 1930, he, like Stratton before him, inherited institutional challenges related to the relationship between the Institute and industry from his predecessor. In *A Widening Sphere*, Philip Alexander's institutional history chronicling the first nine presidents of MIT, this period is characterized as yet another time for reevaluation of MIT's educational strategy. As companies began to develop their own specialized training programs, the value of a school such as MIT to provide industries with a

[136] "Speeches 1923 – 24"; "Speeches 1926-30."

skilled workforce could diminish. Corporation member Frank Jewett and his supporters believed that the best way to regain and maintain prominence was through the production of creative and adaptable engineers who enjoyed a stronger connection to the sciences than could be cultivated by on the job training alone.[137]

In Compton's first Report of the President, in 1930, he characterized this distinctive quality of the MIT experience as one of "technological rather than technical education."[138] This concept was not meant to be a new initiative, but rather a succinct articulation of extant practices. Compton began, "in principle and generally in practice, the Institute has always aimed at technological rather than technical education." [139] Here he made the distinction between "education in fundamental principles and training in their application to important basic processes and problems" and "training in manipulation or technique of routine, through skilled, technical operations."

Similar to his predecessor Stratton, he made some effort to avoid privileging one skill set above the other, and acknowledged that "both types of training have their uses." However, he asserted, "we believe that that type which we try to emphasize is the one which can produce leaders who will be able to handle the big and difficult problems of organization, production and new development." For Compton and MIT's leadership at this time, this abstract characterization of the *technological education* as a program that went beyond the *technical* would be realized by emphasizing the science component of an engineering education in research and curricula.

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[137] Philip Alexander, *A Widening Sphere*, (Cambridge Mass: MIT Press, 2011) 365-7.
[138] "MIT Reports to the President," 1931, 10-11, available at http://libraries.mit.edu/archives/mithistory/presidents-reports.html (accessed 12 February 2011).
[139] "MIT Reports to the President," 1931, 10-11, available at http://libraries.mit.edu/archives/mithistory/presidents-reports.html (accessed 12 February 2011).

This distinction between the *technical* and *technological* provides an entry point into a critical period of negotiation and change for science and engineering education, especially as it relates to the industrial sector in the United States. Coded within this rhetoric of the *technical* and *technological* as educational models, were broader implications for the place of industrially relevant practice in emerging elite engineering education. In addition to formal programs of classroom, laboratory, and fieldwork or practicum components, models for engineering education such as these also incorporated within them implications for strategic planning for the Institute. These models shaped not only rank and funding possibilities for a particular institution, but also disciplinary value judgments about the nature of what was deemed appropriate science within the academy.

In 1931, with a postgraduate population of 536, MIT was responsible for one third of the total advanced degrees awarded in engineering in the United States.[140] Despite this apparently secure positioning in the landscape of engineering higher education, Compton's initial remarks in the *President's Report* were quickly followed by a discussion of "preeminence," including a perceived need to both increase the selectivity of admissions and promote fundamental scientific research. Indeed, Compton had been recruited from the Princeton Physics department specifically to bring greater emphasis to the sciences, following a period characterized by a more explicit business focus at MIT.[141] I argue that Compton's use of the *technical* and the *technological* was more than merely coded language for vocational and elite. Rather, his insistence on this distinction indicated that at this time the boundaries between these two types of engineering education, both of which did offer practical experience, were still fluid and, moreover,

[140] "MIT Reports to the President," 1931, 13, available at http://libraries.mit.edu/archives/mithistory/presidents-reports.html (accessed 12 February 2011).
[141] Alexander, 355-371

that the solidification of a clearer boundary was a key component in maintaining elite status.

Textile Research and the Practice of Education for Industrial Service

The boundary-making process of separating the technological from the technical reflected in the rhetoric of MIT's leaders was also particularly well demonstrated in educational practice through the development of the textile research laboratory, a cross-disciplinary program with strong ties to industrial service. After exploring the structures and tensions of textile research at MIT, I turn to two particular moments in the history of textile education at MIT that nicely illustrate the strategy of creating the *technological* education model and subsequently distancing it from the *technical* or vocational in practice: 1) the discontinuation of the undergraduate program in textile science at the end of the 1930s, and 2) the formalization of the partnership between MIT and The Lowell Textile Institute a decade later.

At MIT, the textile program formally operated at MIT between 1872 and 1993.[142] This field was connected to the core disciplines such as chemistry, physics and mechanical engineering, as well as compatible with broader institutional goals of industrial collaboration. Yet it never found a clear home within a single department and, perhaps as a result, remained always a somewhat peripheral course of study. Unlike other scientific disciplines, such as physics or chemistry that claim for themselves an intellectual "purity" or at least distance from the realm of material goods and their

[142] Backer, Stanley, *100 Years of Textiles at MIT*. (Self Published, 2002), available in MIT Libraries T171.M4224.F533 2002.

production, textile science was fundamentally linked to an already existent industry and a product of everyday use. This commercial connection, especially to a type of production which had been historically (and still is, of course) driven by high volume output at low cost, and for which a significant percentage of the labor force is considered "unskilled" or linked to "craft," also introduces tension about the proper relationship with the elite academic laboratory.[143] The study of textiles often, and of necessity, crosses disciplinary boundaries, involving scientists and engineers from multiple fields working on similar problems from different angles or areas of focus. Chemists involved in textile research may be interested in surface interactions, physicists may be focused on crystal structures or measuring color, while mechanical engineers may study the tensile properties of fibers and fabrics. However, these scientists and engineers are all somewhat unified by their artifact of study, textiles and fibers. This object or product-oriented type of research also highlights disciplinary tensions around the demarcation of textile-related topics of study in relation to the "core" of a particular field. Indeed, it offers a site especially well suited to the problem of defining boundaries for appropriate "fundamental" and "applied" academic research, especially between science and engineering.

Textile research is particularly useful as an example of not only an early problem-driven, cross-disciplinary field of study, but also one that is directly linked to a mature industrial manufacturing sector. In many ways the case of textiles exemplifies the challenges associated with developing a foundational course of study at the industry level. To understand textiles as an industry, one must have considered machinery of

[143] The linkage to the popular conception of textile production as women's work might have also worked against the laboratory.

mass production, materials,[144] process management, consumer behavior, design, and economic conditions that trend toward favoring low cost above other factors. The product itself may be considered as both a raw commodity as well as a finished good with uses ranging from everyday objects to elite consumables and specialized technical applications.[145] The regular sections of *Textile World*,[146] a weekly publication dedicated to industry professionals, also reflect this combination of topics and the necessity for working knowledge across them. A single 100 page issue might collect reports on government regulations, foreign markets and competitors, stock prices, fashion trends, machinery, management and labor issues, chemical and mechanical properties, and testing methods, as well as periodic reports from specialty textile schools including announcements of the graduating class as they entered the job market.

The study of textiles at MIT began in 1872 in the form of a special program, the Lowell School of Practical Design. This program, which operated at MIT's original Boston location, provided training for both men and women in textile design.[147] The facility included seven looms that allowed students to make full commercial-sized textile samples. Tuition for the three-year program was sponsored entirely by the Lowell Institute, an educational foundation established by John Lowell Jr. in 1836.[148] The course typically took students three years to complete, and classes included "1) technical

[144] The majority of materials at this time were derived from natural products such as cotton and wool, although artificial fibers, which were derived from cellulose-based precursors (such as wood pulp) were also being produced. After 1938 with the introduction of nylon at the NY World's Fair, true synthetics and research in polymer science become more prevalent.
[145] Such as military needs, parts of other industrial processes like paper-making and road construction etc.
[146] This particular sample refers to volumes of *Textile World* published in 1930
[147] MIT was then located in Back Bay and did not move to Cambridge until 1916.
The Lowell Institute was possibly best known for informal non-degree granting general educational programming in the form of public lectures by prominent local professors that later expanded into radio broadcasts. Although not specifically textile-related, the Lowell Institute also sponsored an evening based training program for industrial foremen at MIT that ran from 1905 to 1996. 1905 was the graduation year for the first degree completion. "Lowell Institute School records" *1836*-1999, available at http://www.lib.neu.edu/archives
[148] Harriette (Knight) Smith, *The history of the Lowell Institute*, (Boston: Lamson, Wolffe and Company, 1898), 44-46.

manipulations; 2) copying and variation of designs; 3) original designs or composition of patterns; [and] 4) the making of working drawings and finishing of designs."[149] When the program was transferred to the Boston Museum of Fine Arts in 1903 it had already served 1450 students.

Courses in design of textile machinery and mill structure were added in the Department of Mechanical Engineering beginning in 1883. Shortly thereafter in 1885, textile engineering became a specialization within the Bachelor of Science degree in Mechanical Engineering.[150] The initial placement of textile engineering work within Mechanical Engineering reflected the focus of the industry at the time on mechanical innovation. Of course, this had long been the dominant area of productivity in the field of textile production as mechanical improvements increased speed through the replacement of human labor. Yet, as this arena of efficiency gains through mechanization began to plateau, other factors including material properties and finishing procedures garnered new interest. While the textile engineering concentration and Textile Research Laboratory both remained within the administrative structure of the Department of Mechanical Engineering, the disciplinary scope included chemistry, chemical engineering, physics and biology. Management students also wrote theses related to the textile industry although management coursework was not officially offered through the textile engineering program.[151]

Textile work was offered as a coursework topic through traditional classes for graduate and undergraduate students as well as through special workshops offered in the summer for industry and government personnel along with textile faculty from

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[149] Ibid.
[150] Stanley Backer, *100 Years of Textiles at MIT*, 2002, personally published. Only three paragraphs of this 40 page manuscript were devoted to the pre-WWII period.
[151] "Textile Visiting Committee of the Corporation Report," 1937-38, 1938-39, in MIT Archives AC426.

other schools. Coursework in textiles was offered at both the graduate and undergraduate levels and consisted mostly of classes in Mechanical Engineering, but also in Biology and Physics. This section, devoted to the practice of the *technological education*, begins by examining laboratory research, followed by the curriculum and the special programs offered on textile-related topics.

Soon after assuming the presidency of MIT, Samuel W. Stratton sent letters to the departments most obviously associated with the Textile Laboratory soliciting descriptions of their research. The responses to Stratton's inquiries not only described a wide range of active projects involving textiles, but also highlighted a variety of concerns both practical and philosophical that varied by department.[152] Most department chairs or lead researchers took this opportunity to express their concerns about larger disciplinary issues framed within the context of textile research, and more generally applied work of any kind, to the President.

For the Department of Chemistry, there were tensions with regard to the appropriateness of textile-related work in the context of a broader departmental research agenda based on "fundamental" problems.[153] Despite sharing a disciplinary core of chemical principles, Chemical Engineering, in contrast, embraced textile-related applied research work enthusiastically without any reservations at all.[154] Administrative tensions were evident in responses from the Department of Physics as well as Chemistry. They indicated some uncertainty over reporting work carried out on behalf of, and in collaboration with industrial partners to the administration, as well as

[152] MIT Archives, MIT Office of the President AC13, Box 20, Folder 579.
[153] D.A. MacInnes to F.G. Keyes, January 15, 1924, in MIT Archives, MIT Office of the President AC13, Box 20, Folder 579.
F.G. Keyes to S.W. Stratton, January 22, 1924, in MIT Archives, MIT Office of the President AC13, Box 20, Folder 579.
[154] W.K. Lewis to S.W. Stratton, November 9, 1926, in MIT Archives, MIT Office of the President AC13, Box 20, Folder 579.

reluctance to divulge too much information about projects that might have included proprietary knowledge or industrial secrets.[155] Only the Department of Biology and Public Health, which did not appear to be working with industrial partners, sent a response consisting solely of project descriptions. This suggests a possible link between industrial collaboration and ambiguity with regard to reporting and the jurisdiction of information between the administration and research groups.

In a 1924 letter to President Stratton, Dr. F.G. Keyes from the Chemistry Department describes "the matter of research problems presented as Textile Problems submitted by Mr. Humphreys, Secretary of the Wool Manufacturers' Association and Mr. Franklin W. Hobbs, President of Arlington Mills." [156] This phrasing implies a difference between "research problems" routinely engaged by the Department and "Textile Problems" as those undertaken in response to an external influence. Keyes also suggested that some experiments would be better suited to the mill context "with the advice and counsel of those skilled in the standard procedure of the moment." He added "that certain purely scientific investigations are needed to furnish data," implying that the academic laboratory was the appropriate venue for this type of inquiry. Keyes then described a study conducted by Dr. Millard, who had experience in the cotton industry, involving "a systematic study of certain aspects of surface tension theory which appear to be required in order to obtain a satisfactory solution of the technical problem." The letter closed by offering the role of the Department as one "of greater service from the point of view of its equipment and personnel in attacking these purely scientific questions rather than attempting to obtain the solution of the technical difficulties at one step." Once again, Keyes' choice of language makes a clear distinction between

[155] C.L. Norton to S.W. Stratton, November 6, 1926, in MIT Archives, MIT Office of the President AC13, Box 20, Folder 579.
[156] Termed both "Chemical" and "Chemistry" Department

"technical problems," that is the aspects of the work that directly relate to industrial applications, and "purely scientific questions," which are solved through an iterative and less goal-oriented process.[157]

In a letter to Keyes dated a few days earlier, D.A. MacInnes, a Chemistry Department colleague also working on textile research likewise described the distinction between problems suited more to laboratory work than to an industrial setting. For example, he highlighted the problem of scouring or fulling, a process of removing contaminants such as natural oils from wool. MacInnes states that although the group's work on scouring and wool processing problems had yielded some practical results, "important pure science problems must first be solved" in order to properly interpret their findings. For example, in order to account for detergency properties of soap and soap alkali mixtures they needed to conduct experiments on surface tension and emulsification among others. It is these "fundamental, theoretical problems which can be carried out efficiently in our laboratories [that] are much more the province of research in this Laboratory and the Chemistry Department rather than investigations on scouring which include not only these problems involving a smaller number of variables, but also the properties of the wool etc." He went on to assert, "nothing fundamental will be found out about fulling wool until we know more about the chemical and physical properties of wool." Here MacInnes makes the distinction between the overall industrial process of fulling and a scientific understanding of this process, which involved a clearer comprehension of the individual components and how they each contributed to the combined effect recognized as fulling. He continued, "much valuable work from a pure science point of view has been carried out by Jacques Loeb

[157] F.G. Keyes to S.W. Stratton, January 22, 1924, in MIT Archives, MIT Office of the President AC13, Box 20, Folder 579.

and others, which will eventually, I think, give us the data for a real scientific study of fulling. For the present the results could be little better than a rule of thumb, and could be carried out to much better advantage by the mills themselves." MacInnes draws the distinction between problems well-suited for the academic laboratory such as characterizations of inherent material properties, and overall effects of certain chemicals or processes on these properties as practice-based "rule(s) of thumb." However, he did not exclude industrial processes from the characterization of a "real scientific study," as long as the multiple variables involved in processes such as fulling could be disaggregated. [158]

Administrative tensions over the jurisdiction of industrial research as private or outside of the normal scope of departmental projects is also evident in the responses to President Stratton's request for information. Charles Norton, Professor of Physics, though engaged in textile work himself, was quite brief in his description of "the only directly related textile work conducted in the Department as of an extremely confidential nature," a project involving measurement of yarn diameter during the spinning process. He also reported that machines were specially built and tested for this project. There was further occasional work on the physical properties of fibers and fabrics including fire-proofing (fire retardancy).[159] Finally, Norton added that some work on the color of fabrics was conducted for the silk industry using the spectrum photometer (spectrophotometer).[160] In a 1926 letter that described the state of textile research in the Chemistry Department, Keyes reported to Stratton that he had some difficulty identifying staff members engaged in textile related work because "the work

[158] D.A. MacInnes to F.G. Keyes, January 15, 1924, in MIT Archives, MIT Office of the President AC13, Box 20, Folder 579.
[159] Contemporary terms for methods or materials are noted in parentheses where applicable.
[160] C.L. Norton to S.W. Stratton, November 6, 1926, in MIT Archives, MIT Office of the President AC13, Box 20, Folder 579.

that has been done has been of a private nature and not connected officially, in general, with the Institute." He then went on to briefly describe the work of four researchers: Prof. E.B Millard investigating fiber properties; Prof. Phelan who has "acted in an advisory and consulting capacity for some mills," work which he describes as "desultory" and without a specific research problem; Prof. Mulliken, "one of the best informed dyestuffs chemists in the country" who is only engaged occasionally with the textile industry; and lastly, Theodore Shedlovsky who is doing work through the Division of Industrial Cooperation and Research for F.C. Huyck & Sons Co. of Albany, New York. [161] It is worth noting that only one of the four, Shedlovsky, was engaged in industrial work through the Institute office specifically devoted to coordinating such efforts. The others were also not obliged to provide detailed information about their industrial engagements. This issue came to a critical head in the 1930s with the reinvention of the Division of Industrial Cooperation as a centralized clearinghouse for corporate work. A more focused discussion of the Division can be found in the section on entrepreneurial laboratory management.

Only the Department of Biology and Public Health answered Stratton with a simple project report, devoid of commentary on the relative merits of their particular discipline or on the appropriateness of textile-related or applied work in the research university. In his 1926 letter of response, department head, S.C. Prescott describes "the extent to which mildewing and similar troubles developing in textiles have been studied" by his group. [162] Research included interaction with fungi, bacteria and insects, with projects involving mildew and bacterial spotting of cotton and wool, as well as

[161] F.G. Keyes to S.W. Stratton, November 10, 1926, in MIT Archives, MIT Office of the President AC13, Box 20, Folder 579; Many of the companies mentioned in correspondence and department records are just mentioned by name and have no other associated information.
[162] S.C. Prescott to S.W. Stratton, November 4, 1926, in MIT Archives, MIT Office of the President AC13, Box 20, Folder 579.

moth resistance of wool and mohair. Due to the biological nature of these projects and the incubation time required for contaminants to manifest their destructive capacity, their research timeframe was a relatively long one, unlike that for all of the other disciplinary participants in textile-related research. Prescott describes the use of mineral salts of organic acids to prevent mildew as a "subject that opens a broad field for industrial research." However, he did not mention specific industrial sponsorship for this research.

In contrast to the guarded replies from Physics and Chemistry, and the matter-of-fact reporting from Biology and Public Health, the Department of Chemical Engineering led by W.K. Lewis listed specific project descriptions with enthusiasm. He asserted that this Department "feels particularly fitted to attack such textile problems as the washing and preparation of raw fibers and the bleaching, dyeing and finishing of textile materials."[163] The Research Laboratory of Applied Chemistry, part of the Department of Chemical Engineering, was engaged in cooperative research with seventeen Massachusetts laundries on process streamlining, which resulted in a presentation at the national conference of the laundry industry, which is closely related to that of industrial textile finishing. Yet another project involved the x-ray characterization of cellulose, the main component of cotton and precursor for artificial fibers such as rayon and acetate. This work provided material for student theses in addition to "paid research" and was partially sponsored by a company identified as Cheney Brothers. These multiple types of research projects sponsored by a single company are worth noting. In many respects, it was the student thesis projects that served to bridge the priorities of the departments and industrial partners by teaching

[163] W.K. Lewis to S.W. Stratton, November 9, 1926, in MIT Archives, MIT Office of the President AC13, Box 20, Folder 579.

with 'real world problems' while generating useful data for the corporate sponsor. Work described as "paid research," on the other hand, was more likely treated as contract-based problem solving. The previous year's research, which was expected to continue, included student theses conducted with Lewis Manufacturing Company and involved various testing methods for drying of textiles, loom varnishes, and sizing materials such as starch, dextrins and glues.

Finally, the Department of Mechanical Engineering, unlike those from the other departments, characterized their own work within the teaching mission of their laboratory. In a 1923 letter to E.F. Miller, Professor of Mechanical Engineering, his colleague, George B. Haven, who was "in charge of the Textile Option and Laboratory" asserted, "the work of this laboratory is of course two-fold; first and most important, the training of undergraduate students as mill and textile engineers; second, the pursuit of research problems."[164] The research projects "which at present are very numerous, among the various contractors under the Technology plan," were also framed within the teaching agenda. [165]

Haven was "glad to respond" to Stratton's inquiry about staff engaged in textile work. He reported that forty percent of his own time was devoted to textile work. His colleagues included Edward R. Schwarz, who was full-time; George W. Swett and Arthur L. Townsend, who both devoted ten percent of their time specifically to textile machinery; and Arthur L. Underwood, who spent ten percent of his time on textile work. Two of the core courses in textiles offered to undergraduates, "Mechanisms of Cotton Machinery" and "Testing of Mechanical Fabrics," had eighty-seven and eighty-

[164] This is the title that Prof. Haven used to identify his role, although it seems a bit unwieldy, he seems to be consistently referred to in this way and not as a director, head or chair.
[165] E.F. Miller to S.W. Stratton, October 25, 1923, in MIT Archives, MIT Office of the President AC13, Box 20, Folder 579.

four students enrolled respectively in 1923. Haven also listed twenty-five master's thesis topics as "under active or assured progress." Every one of these were supervised by either himself or Schwarz. Thirteen of these projects were underway; the remaining twelve were waiting to be assigned to students. The projects included analysis of fiber, yarn or fabric properties that impact processing and quality, such as tensile strength, moisture regain, elongation, and abrasion. He also added in closing, "we shall have a good many others during the next few months when the senior class comes up for thesis assignments."[166] This response to Stratton not only highlights the diversity of textile related research topics engaged by the Department of Mechanical Engineering as it related to textiles, but also the way that this work was fundamentally connected to their curriculum.

At the undergraduate level, there were nine textile related courses. Five were offered through the Department of Mechanical Engineering: "2.05 Mechanisms of Cotton Machinery," "2.35 Testing Materials Laboratory," "2.30 Materials of Engineering," "2.87 Textile Engineering," and "2.871 Textile Laboratory." Schwarz taught two of these (2.35, 2.871) in addition to co-teaching course 2.87 with Haven who also independently taught 2.30. [167] Swett had one course for undergraduates, "Mechanisms of Cotton Machinery." Haven's class, "2.30 Materials of Engineering" had the largest enrollment at 125 and included third and fourth year students from Mechanical Engineering, Physics, Biology and the program in Mill Engineering. The class on cotton machinery, which consisted of four lectures and four recitations, with an estimated eight-hour prep time and three laboratory exercises, had sixty third-year

[166] G.B. Haven to S.W. Stratton, October 29, 1926, in MIT Archives, MIT Office of the President AC13, Box 20, Folder 579.
[167] At MIT, departments have both names and course numbers. Classes that begin 2.x, 8.x, 7.x are from Mechanical Engineering, Physics and Biology respectively.

students in Mechanical Engineering enrolled. The class with the smallest enrollment, six plus two "partial students," was "2.87 Textile Engineering." This class, co-taught by Haven and Schwarz, also appeared to carry the heaviest workload, including thirty lectures, sixty laboratory exercises and an estimated thirty hours of preparation for each student. Three of the courses in the textile requirements were designated as physics: "8.07 Precision of Measurements," "8.17 Geometrical Optics," and "8.18 Physical Optics." These appeared to be concerned with general laboratory training and microscopy, a critical skill for fiber study. The Department of Biology also contributed one course, "7.07 Mycology."[168] This would have been especially valuable to anyone involved in any type of textile finishing at an industrial scale, since fungal growth was a serious hazard during both treatment in liquid baths and the drying process.

At the graduate level, 1928 marked the first year that the program offered formalized advanced coursework in textiles that led to a Master of Science degree. Previously, masters students appeared to have been trained on a more *ad hoc* basis and their experience was almost exclusively shaped by their thesis work. This graduate program consisted of nine subjects, plus an estimated four hundred hour thesis component. Professors Haven and Schwarz, as they had with the undergraduate curriculum, carried a significant portion of the teaching load, including: "2.872 Design of Cotton Machinery," "2.874 Dynamics of Textile Machinery," "2.875 Textile Technical Analysis;" "2.873 Design of Wool Working Machinery," and "2.876 Principles of Fabric Structure" respectively. Other courses included Swett's "2.09 design of Automatic Machinery," and Williams' "2.341 Physical Metallurgy." The Physics Department offered two classes, "8.191 Microscope Theory and Photo" as well as "8.99

[168] "Textile Instruction and Research at Massachusetts Institute of Technology, 5/7/28," in MIT Archives, MIT Office of the President AC13, Box 20, Folder 579.

Physical Instruments."[169] Similar to the undergraduate requirements, the masters level components provided by the Physics Department were focused on recent developments in laboratory and analytical techniques.

Haven portrayed the Textile Laboratory, located primarily in Building 3, as one of constant activity and unique relevance to the state of the art in textile technology. "The research work coming to the Institute is wholly of such a refined character that the textile testing laboratory is in considerable demand for this class of work," he wrote to E.F. Miller, then in charge of the Department of Mechanical Engineering. [170] Haven highlighted the laboratory's role in "litigations, rejections and acceptances" regarding various properties including "strengths, weights and elasticity." This is noteworthy because it demonstrates that the laboratory was also engaged in some capacity with regulatory standards in addition to industrial projects.[171] Although he admitted that "our apparatus is, in a sense, sufficient" for use by undergraduates and graduate student requirements, "there [were] numerous improvements which could make our work more accurate and enable us to carry out research questions with more dispatch."[172] This characterization of the laboratory and its work was, not surprisingly, framed within the context of requesting capital resources that would enable numerous improvements to its machinery and physical environment.

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[169] "Textile Instruction and Research at Massachusetts Institute of Technology, 5/7/28," MIT Archives.
[170] Buildings on the MIT campus are also commonly referred to by numerical designation as their name. Although this is also the case for departments, these numbers are unrelated to one another; G.B. Haven to E.R. Miller, October 25, 1923, in MIT Archives, MIT Office of the President AC13, Box 20, Folder 579.
[171] There was no other mention of this type of work, though further study on the involvement of the laboratory in government regulations and litigation would be useful. This is also noteworthy considering Stratton's connection to the Bureau of Standards and his interest in positioning MIT at a productive crossroads between government and industry. However, in a 1939 report on the Division of Industrial Cooperation it was noted that the performance of testing services by MIT labs was strongly discouraged since it was of "transient value" and was seen as creating competition with commercial testing labs and thus "improper."
"Division of Industrial Cooperation 1931- 1939," in MIT Archives, AC4, Box 70 Folder 13.
[172] G.B. Haven to E.R. Miller, October 25, 1923, in MIT Archives, MIT Office of the President AC13, Box 20, Folder 579.

Formalized coursework that included learning outside the classroom setting also contributed an important component of the "technological education." Fourth year students in the Textile Engineering program typically devoted 110 hours to the design of a cotton mill, "complete in every particular from store-house to weave-shed inclusive, for the production of print goods in the grey."[173] This project included full calculations for capacity, energy and staffing for a 50,000 spindle mill as well as a forty hour lab component "of an advanced character" to understand "weights, losses, drafts etc. for the various machines in operation." In addition to study of "several hundred lantern slides" that illustrate current mill practices, the entire class made at least one full day excursion to a production facility nearby, most often in Lawrence, Lowell or Manchester. [174]

Cooperative courses, in which students split their time between the classroom and the factory setting, also served as the medium for combining theoretical training with industrial experience. Unlike internship programs initiated by companies, such as General Electric's Thomson and Edison Clubs that were typically designed to accelerate recent college graduates into corporate life, cooperative programs between universities and industrial partners were designed for undergraduates still engaged in coursework. Programs included work experience among the degree requirements, and thus could extend to a total of six years rather than the standard four normally required for an undergraduate degree.[175] Although these types of programs combined "mind and hand," they were not without their critics, or at the very least a group of academics and industrialists who showed a real "lack of enthusiasm." [176] A report by a committee of the

[173] G.B. Haven to E.R. Miller, October 25, 1923, in MIT Archives, MIT Office of the President AC13, Box 20, Folder 579.
[174] G.B. Haven to E.R. Miller, October 25, 1923, in MIT Archives.
[175] Carlson, "The MIT-GE Cooperative Engineering Course," 16.
[176] Carlson,15; The motto of MIT, "mens et manus" acknowledges the combination of theory and practice as a fundamental principle for the Institute.

faculty on the GE cooperative course warned that students might develop "a narrow, mechanical point of view" that would hinder them from reaching their potential as "engineers of a high originative type."[177] Historian of science and technology, W.B. Carlson argues that the eventual success of this program could be attributed to perseverance on the part of the Institute to overcome "corporate ambivalence" during uncertain economic times. [178]

In the field of textiles, the cooperative model of research and education with industrial partners however, seemed to carry yet a different connotation and its own set of challenges. The National Association of Cotton Manufacturers reported slow but satisfactory progress for "cooperative mill research" but it was not clear whether this plan included academic partners.[179] In this case, various mills were brought together to address mutually shared industrial problems through their national trade organization. At MIT's textile program, G.B. Haven reported under the section heading, "Cooperative Work," that "a considerable program of research" was under investigation with Seamans & Cobb on the effects of moisture on thread strength, as well as a project on super-twisted tire cords with Fisk Rubber Co. through the Division of Industrial Cooperation.[180] This model of cooperation, common in the MIT labs, involved industry sponsored research projects that were conducted on the MIT campus. Many of these projects yielded student theses while simultaneously contributing to an important part of the curriculum.

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[177] Carlson, 15; "Report of the Committee of the Faculty on the Proposed Cooperative Course in Electrical Engineering" December 1907.
[178] Carlson, 15.
[179] "Report of the Research Committee," October 31, 1923, in MIT Archives, MIT Office of the President AC13, Box 20, Folder 579.
[180] G.B. Haven to S.W. Stratton, May 3, 1928, in MIT Archives, MIT Office of the President AC13, Box 20, Folder 579.

Although a cooperative course that included work at a mill or factory site was not established for textile training at MIT, this is still an important model to mention, as it was a critical component of the "technological education" on offer elsewhere at the Institute, most notably in the Department of Electrical Engineering. Carlson includes the cooperative course between MIT and GE as an integral part of D.C. Jackson's plan to make his the largest electrical engineering program in the United States in 1925, intended to foster prestige, increase enrollments, yield additional revenue, and secure jobs for graduates while also promoting closer ties with industry.[181]

The textile program also engaged in alternative coursework models, which served to diversify the educational experience, reach broader audiences and strengthen professional connections outside of MIT. In addition to traditional classes, short-term workshops on textile topics held during the summer session and on weekends enjoyed both consistently high attendance and financial success. These short courses were aimed at working professionals in industry, government and education, as well as for college students from other institutions. In 1938, when a Visiting Committee of the Corporation was formed to evaluate the textile program, both the "weekend mill group" and the summer session were oversubscribed, and forced to turn away qualified potentially tuition-paying participants during a time when budgetary anxiety was a primary concern for the overall program in textile education. The "weekend mill group" accepted twenty-five from over forty applicants, and its financial viability was appreciatively noted by the Visiting Committee. They reported "that this type of instruction is entirely self-supporting and it is anticipated that it will leave a small balance for the disposition and the general funds of the Institute after small amounts are

[181] Carlson, 15–18.

paid for the additional time taken by the instructing staff and possibly a small allocation made for research purposes." [182] Elsewhere in the report were a series of criticisms related to funding and enrollment. This context makes the popularity, financial success and praise from the committee in reference to the courses offered outside the traditional curriculum all the more noteworthy.

The summer session course was capped at fourteen students, three of whom, the committee report noted, were "qualified and experienced teachers of household economics coming to us from the West and Middle West – in one case taking the course again after a period of 10yrs." [183] These students were perceived as a marker for success, as their presence and willingness to travel "indicat[ed] not only the interest in the work but the fact that the educational program had been steadily developing over that period." [184] The summer course model continued and was still an integral part of the teaching component of the program during the 1960s and 70s. By this time the program in textiles had since been renamed the Fibers and Polymers Laboratory. Under the direction of Professor Stanley Backer, the summer course served as a forum to showcase graduate student research and attract prestigious seminar speakers from abroad. [185]

TWO CRITICAL MOMENTS IN THE TEXTILE PROGRAM

In practice, the topic of textile research serves to highlight diversity in both projects and approaches taken by various departments, as well as the variety of

[182] "Textile Visiting Committee of the Corporation Report," 1937-38, 1938-39, in MIT Archives AC426.
[183] Ibid.
[184] Ibid.
[185] Backer, *100 Years of Textiles at MIT*, 5, 20, 21.

coursework offerings for undergraduate, graduate and special students. In many ways, the Visiting Committee of the Corporation that was formed in 1937 to investigate the textile program attests to this nearly unwieldy diversity and to a growing perception on the part of MIT leaders that a re-centering of the educational program and streamlining of finances was necessary. The outcome of this committee's recommendations, which included the dissolution of the undergraduate program in textiles among other restructuring measures, transformed the direction of the textile program both within MIT, and also in relation to external partners, further solidifying the boundary between the *technical* and *technological*. MIT's relationship with the Lowell Textile Institute (LTI),[186] further illustrated the boundary-making practices employed by MIT leadership between the *technical* and *technological* in the context of science and engineering education and its relationship to industrial service.

In the 1931 *President's Report*, shortly following the characterization of the *technical* and *technological* and within the discussion of strategy for maintaining competitiveness, Compton suggested both a streamlining of undergraduate coursework and improved flexibility for postgraduate courses. In order to provide a more uniform experience, freshmen would take a prescribed set of courses; specialization would be allowed only following a choice during sophomore year between engineering and science. However, at the more specialized graduate level Compton acknowledged that, "the interrelations between various branches of science and engineering are so complicated that there are many borderline cases or important special activities which

[186] This was the name for the majority of the time period of interest. It was founded as the Lowell Textile School in 1895 then changed to Lowell Textile Institute in 1928, Lowell Technological Institute in 1954, and University of Lowell in 1975 (created by a merger between the Lowell Technological Institute and Lowell State College) Lowell joined the University of Massachusetts system in 1991.

have their roots equally in several different departments."[187] For this reason a student could propose a course of study that crossed departments in order to create his (or her) own particular specialization. Within this framework of foundational undergraduate study and delayed specialization, the textile specialization for undergraduates within Mechanical Engineering seemed a poor fit. Yet, the graduate component with its highly cross-disciplinary and specialized nature remained appropriate.

By the late 1930s, however, the future of the textile program in its entirety was under scrutiny. In 1937, a Visiting Committee of the Corporation, including President Compton, corporation members, and Professor Schwarz representing the textile program, was formed to evaluate and make recommendations about the continuation of textile education at MIT. At the time, much progress depended on an as yet unconfirmed ten thousand dollar grant from the Textile Foundation, an organization comprised of influential companies that funded research for the mutual benefit of the textile industry. This created a problematic situation since the program could not continue without the grant; yet, not surprisingly, the Textile Foundation was reluctant to fund a program with a questionable future. The issues surrounding this particular grant raised a larger question about funding structures at MIT. Franklin W. Hobbs, the chairman of the visiting committee, argued strongly for reconsideration of the role that the Textile Foundation grant should play in determining the fate of the program. He stated "is it not in harmony with the policy of centralization to obligate the Foundation to place $10,000 at MIT for 3 years; and that it would be wiser to allot $5,000 for one year" for research on particular topics related to microscopy and characterization of

[187] *MIT Reports to the President* 1931

fiber properties.[188] Originally the continuation of the textile program was phrased as contingent upon receipt of the full Textile Foundation grant. The advisors recommended that the partial grant should only be contingent upon the continuation of the textile program by MIT. However, although the grant would make some additional research possible for the coming year, "it did not relieve to any major degree the financial load being borne by MIT ...and might even necessitate additional expense" to fully carry out the proposed projects.

While the case of funding formed a practical obstacle for the future of the laboratory, it also served to highlight broader concerns on the part of MIT's leadership about conducting industry-related work in an academic laboratory. The visiting committee's report makes a clear distinction between *fundamental* research topics, and *direct research* that was for the benefit of a specific company. Broadening the scope of *fundamental* research in fibrous materials was deemed an appropriate use for Institute funds. However, "research in a field beneficial to a single industry," especially one in "which adequate support from the industry is lacking," was unacceptable.[189] A general lack of enthusiasm on the part of the textile industry as a whole seemed to form an implicit critique throughout the report. In retrospect, the committee felt that in the future an effort should be made to include industrial representatives on such advisory bodies. They also left room for reconsideration of textile research should greater industry support be found which "would warrant intensive investigation of strictly textile problems as such."[190]

The Visiting Committee flagged the problem of declining undergraduate enrollments, but balanced that assessment with praise for the growing emphasis placed

[188] "Textile Visiting Committee of the Corporation Report," MIT Archives.
[189] Ibid.
[190] Ibid.

on graduate training. They noted that those interested in textiles were not just students from the Department of Mechanical Engineering; indeed, they reported that "the number of men coming directly from ME has been very small for the past eight or ten years." This trend also correlated to a shift in "emphasis from mill engineering to research and technology- a field not being similarly covered elsewhere." They recommended that the undergraduate course be discontinued and that these topics be transferred to graduate level electives. The decision to eliminate the undergraduate coursework was framed as an opportunity to expand a unique aspect of the program in textiles, namely graduate research, while causing little disruption for current undergraduates. "The proposed change will work no hardship on men in the Course in Mechanical Engineering, since they will still have the usual choice of elective courses in textiles. The instruction program would be of wider appeal and broader in scope as a result of the change. "[191]

By focusing on graduate education and research, they also hoped to secure MIT's niche in this aspect of textile education, while strengthening relations with others such as the Lowell Textile School, which offered only undergraduate and vocational training. "It is hoped that continued and extended cooperation between the Mass. Inst. Of Tech and the textile schools would be assured."[192] Both schools shared a location in New England, where the United States textile industry had flourished at the end of the 19th century, mostly due to mechanical innovation. Despite being only twenty-five miles apart, they developed in a quite different direction with respect to textile studies. MIT, as a private science and engineering institute, crafted its program within the context of the *technological education* referenced earlier. Lowell, as a public

[191] Ibid.
[192] Ibid.

institution, physically situated in the very heart of the mill region, was driven toward technical education by the pressing need for skilled workers in this sector. The pairing of these two schools and their approach to industrially-relevant engineering education serve to both illustrate and problematize this *technical* and *technological* divide during its formative stage. The relationship with the Lowell Textile Institute demonstrates one critical way that MIT leaders sought to separate their institute from a more vocational model during early stages of development when perhaps the boundaries were still being created. However, once both schools had developed more specialized educational niches for their respective aspects of textile studies, they developed a more complementary relationship between the two institutions.

By this time MIT and the Lowell Textile Institute already had a long history of collaboration at varying levels of interaction and formality. As described in 1911 by Lowell's president, and MIT alumnus, Charles Eames, this school was originally envisioned as a department within MIT. However, uncertainty with regard to support from MIT, local industry leaders anxious to create a program to suit their needs instead decided to invest in an independent school in the mill region itself.[193] Deeply embedded in the day-to-day problems of the textile industry, the Lowell Institute worked in more of a partnership model, rather than the consulting mode associated with MIT where the research was predominantly focused on chemical bench-scale experimentation. The Lowell facilities were outfitted with full-scale machinery donated by local manufacturers in order to simulate the mill environment as accurately as possible. In a 1911 article addressed to the National Association of Cotton Manufacturers, Eames highlighted the added difficulties of education for the industrial context, "in the study of mathematics or

[193] Charles Eames Papers, Center for Lowell History, Lowell MA, Box 23, Folder 4.

science, it is comparatively easy to manipulate various quantities and determine the effect of each upon the result in any given experiment or test. But the same methods cannot be practised [*sic*] quantitatively," in factory practice.[194]

During the mid-1920s MIT engaged in limited collaboration with the then-called Lowell Textile School, mostly in the form of lending out facilities for students to carry out experiments that were not possible to conduct on the Lowell campus itself. For example, in 1926 a senior engaged in a project studying card clothing (a comb-like tool required to process cotton on an industrial scale) came to MIT to use the Scott Horizontal Testing machine, since the one available at Lowell was not strong enough to break this type of heavy industrial material.[195]

Graduates of Lowell and other similar institutions often came to MIT for further graduate study or to work on a bachelor of science in a more focused chemistry or physics related program. Sometimes upon arrival they were required to take extra coursework, especially in mathematics.[196] This was not always the case, however. Students with "approved standing" from Lowell made a seamless transition into graduate student life and advanced textile coursework.[197] MIT also held funds aside for graduates of the LTI to pursue graduate study through a grant from the Proprietors of the Locks and Canals of the Merrimac River. The New England Textile Foundation sponsored yet other additional scholarships for graduate study at MIT in the late 1940s. Many prominent figures in the region held degrees from both institutions, including LTI's president in the 1940s, Kenneth R. Fox.

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[194] Ibid.
[195] "Lowell Textile School 1926-27," MIT Archives, AC13, Box 13, Folder 383,
[196] "Proposed courses of study at the Institute in relation to the textile industry," in MIT Archives, AC13, Box 13, Folder 587.
[197] This was the case for Jerome Franks, Brooklyn NY and Richard Morey Sawyer, Winchester MA in 1928. "Textile Instruction and Research at Massachusetts Institute of Technology, 5/7/28," in MIT Archives, MIT Office of the President AC13, Box 20, Folder 579.

In 1949, MIT and LTI, the latter having been recently accredited by the Commonwealth of Massachusetts (a process in which MIT took part),[198] announced an official plan to "pool their facilities for the benefit of graduate and undergraduate students."[199] This arrangement included: sharing of library resources on both campuses; opportunities for further study in chemistry, mathematics, business, and engineering in addition to textile technology for Lowell students; and an opportunity for MIT students to use textile manufacturing and finishing machinery during summer courses or other special sessions. This provision also developed plans for joint faculty seminars and classes. Both institutions now had demarcated their own educational jurisdictions in the textile field. MIT's activities in textile research were predominantly at the graduate level within a broader general engineering program. Lowell focused on undergraduate training specifically for the textile industry. Despite the original conception of Lowell as a department within MIT, their long standing informal relationship, and their often-shared faculty and equipment, it was not until both institutions had solidified their own unique and externally accredited identities within the textile field and industrial service more broadly that a formalized agreement was created.

The relationship between MIT and LTI serves to nicely clarify the line drawn between industry-specific or *technical* education and the *technological* program that aimed to create an elite generalist with an aptitude for specialized skills during a time when the boundary between vocational and elite engineering programs was still in flux. Perhaps the very existence of this nearby institution operating in partnership with, and in service to local industrialists also kept the field of textiles from integrating itself fully

[198] "Lowell Technological Institute," in MIT Archives, AC 4, Box 140, Folder 6.
[199] MIT News Office Press Release: October 3rd, 1949, in MIT Archives, AC4, Box 140, folder 6.

into the curriculum at MIT. It remained in the category of special topic or at the project level, rather than joining the foundational curriculum. From the perspective of MIT leadership at the time, a connection with the Lowell Textile Institute could provide stable opportunities for students to be more closely acquainted with industrial practice. Through a single partnership, the benefit of an industrial cooperative course with specific companies, which was often difficult to manage and support,[200] could be incorporated into a less specialized, highly flexible undergraduate program structure that emphasized a foundation in basic science and engineering. When MIT discontinued the undergraduate coursework in textiles in 1938, a clear distinction between the roles of both institutions was solidified. To paraphrase Compton, Lowell would provide *technical* training in the field of textiles with an emphasis on mill-specific problems at the undergraduate level, whereas MIT would focus on *technological* education through graduate coursework and research grounded in the basic sciences.

The challenges of maintaining programs for industrial service, through the creation of new types of industrial research partnerships and those of maintaining flexible educational programs, were demonstrated in the cases of the Tech Plan, Division of Industrial Cooperation, RLAC and the program in textile research. This strategic, yet often difficult to sustain, combination of academic and industrial actors would prove vital to setting the groundwork for the innovation economy. This emphasis on knowledge production as an economic driver would become a defining characteristic of the continued economic growth of the United States throughout the 20th century. This system would develop even greater momentum with the onset of World War II as government actors gained further agency within already established

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[200] Carlson, 536-569.

academic and industrial networks. Understood through trajectories of successful business ventures, collaborative cross-disciplinary laboratories, or the heated controversies that surrounded appropriate boundaries between the academic ivory tower and the trappings of industry-specific problems, these links between academic and industrial partners, in turn, provide insight into the mechanisms underpinning the American innovation society. These partnerships offered different, yet mutually compatible benefits to both academic institutions and industrial organizations. For the institutions of higher education, close ties to businesses created not only a potential new source of revenue, but also a way to solidify the place of a college education as both relevant and necessary for individual social mobility and overall economic growth. Companies in turn were given access to cutting edge research without having to invest in the creation of their own in-house research and development divisions (though many would come to do so later on), as well as to a guaranteed supply of young talent from which to develop their own workforce and scientific programs. Not surprisingly, the twin issues of job placement and stability were critical for both industrial and academic organizations.

The MIT model combined the outflow of basic research and the influx of particular industrial concerns that would in turn shape future research agendas. Dedicated and centralized institutional structures replaced ad hoc and informal arrangements between individual researchers and companies. These initiatives, such as the Office for Industrial Cooperation, became vital support structures as the scope and scale of the collaborative programs increased. However, as we will see in the chapter that follows, institutional change and the broader development of industrial science in America - not only as a part of the economy but also of its popular culture - was predicated on far more than just the creation of specialized administrative offices and research centers. In the next chapter, I argue that this process of change, at the Mellon Institute, MIT, and within their larger networks, had to be fundamentally linked to their powerful, shared stories that articulated goals and values.

CHAPTER 4
NARRATIVES OF PROGRESS AND INNOVATION: A LANDSCAPE FOR TECHNOLOGICAL IMAGINATION

"In this story the moral must come first: if you have a big idea, bigger perhaps than you can master alone, *write a book about it.* The chances are that somebody will read your book and, if sufficiently impressed, may do something about it."[201] This is how the editor of Chemical and Metallurgical Engineering, Sidney Kirkpatrick, began his article on the Mellon Institute and the legacy of Robert Kennedy Duncan to commemorate the opening of the Mellon Institute's "New Building" in 1937. Indeed, it was Duncan's 1907 book, *The Chemistry of Commerce* that attracted the attention of the Mellons and eventually led to the formation of the Mellon Institute. Praised by his colleague, and former student, Edward Weidlein, as a "poet, author and scientist,"[202] Duncan was well respected for his ability to communicate across diverse audiences and to build enthusiasm for his vision of industrial science and human progress.

Through narrative, that is, the shared and collected stories that resonate far beyond the individual, people are able to make sense of and order their world.[203] In this chapter, I focus on practices of narrative-making as they were used in the American popular imagination to create legitimacy for scientific enterprise both in the service of

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[201] Sidney D. Kirkpatrick, Research – Mellon's Magnificent Obsession *Chemical and Metallurgical Engineering* Vol 44 No 6 June 1937.
[202] Klug ed. 20
[203] Per H. Hansen "Business History: A Cultural and Narrative Approach" *Business History Review* 86 (Winter 2012): 693-717

industrial science in the early 20th century and later for basic research. Per H. Hansen, in his presidential address to the Business History Conference in Frankfurt in March, 2014, made an impassioned call for the adoption of an analytical approach to interpreting narrative, as well as an appreciation for the construction of cultural meaning as a critical part of understanding institutional change. He argued, "economic and business phenomena have cultural foundations. Historian's explanations of and search for understanding must therefore pay attention not only to contextual and cultural specificity but also to processes of signification and sensemaking and how they matter for decision-making actions."[204] Following his lead, I utilize both texts and the built environment to argue that narratives of progress were essential components of institutional and industrial change across the critical early decades of the 20th century. The built environment offers rich material for analysis of narrative from the monumental scale of academic buildings to the small details of particular artifacts in use or on display in industrial science exhibits. Specific institutional mechanisms for academic-industrial cooperation, no matter how well organized, thoughtfully conceived, or generously funded, could not stand alone without a foundational narrative to give them broader purpose and context. Such narratives served to link familiar or even prosaic things and practices to a compelling and achievable vision of a better future.

I argue that the creation of "narratives of progress" that could help to establish the legitimacy and importance of industrial science, both as an academic discipline, and as a key to economic development and improved quality of life, became factors for institutional change that helped to establish infrastructure for innovation. By narratives of progress, I mean shared stories and rhetoric that are conceived for and deployed in

[204] Ibid.

the service of a particular idea, namely creating a better world through the enterprise of science. The rhetoric of progress played a major role in shaping the internal institutional change at Mellon Institute and MIT, as well as in framing the broader understanding of the value of science as applied to everyday life. These narratives of progress not only connected science and business, but also linked this powerful combination of interests to material abundance and overall national strength. A nation that was efficiently organized in the enterprise of science could be simultaneously a collaborator and a competitor in the technological arena on an international stage.

I approach narratives of progress through both text and the built environment. The published work of Duncan, Weidlein and Hamor on science and industry provide the foundation for my analysis of narrative and public engagement with science. In addition to textual narrative, I draw upon examples of what I will call experiential narrative such as those manifested by the architectural styles developed for institutional buildings or in the context of public exhibitions. Features of the built environment, whether in the form of enduring structures or ephemeral displays, added a participatory element to the construction of narrative. In this type of setting, the human body, whether as an employee or visitor, might also become a part of the narrative through their own movement within the relevant space. As one particularly rich way of approaching the experiential narrative, this chapter introduces a third "Institute for Innovation," the Smithsonian Institution. This public institution, which sought to communicate about industrial science to a broad audience through public exhibits provides a complementary example to the cases that we have already explored in the Mellon Institute for Industrial Research and MIT. In particular, the challenges faced by the Section on Chemical Technology at the Smithsonian highlight the difficulty of communicating to a general visitorship the educational value of contemporary industrial science beyond promoting business interests. Linked to this museum example, yet critically different in terms of overall messaging, I employ a complementary case from a world's fair to illustrate how businesses working in industrial science successfully combined consumer education and entertainment to link their brands to narratives of progress.

TOWARD AN "ERA OF GRACIOUS LIVING:" TEXTUAL NARRATIVES OF THE SCIENTIFIC ENTERPRISE

"The scientific progress of a country is dependent on the appreciation of science by an interested public as well as on the support and encouragement of wealthy men."[205] For Edward R. Weidlein and William A. Hamor this science communication aimed at a broad audience was a vital prerequisite for the success of science and human progress as a whole. Indeed, they even devoted an entire chapter in their 1936 book, *Glances at Industrial Science Through Walks and Talks at the Mellon Institute* to "Literary Activities of Industrial Science," with a subsection on "The Popularization of Science." They lauded that "in America we have witnessed a nation-wide flowering of interest in science that is without precedent." [206] For these Mellon Institute leaders, the enterprise of science should act as a bridge to connect classes of patrons and ordinary people through a common ideal of progress through productivity.

> "Many of the greatest strides have been made, it is true, through the patronage of philanthropists. But a comprehensive, sound body of science can no more be built without the credence and sympathy and even the practical assistance of a large part of the population than could the Cathedral of Chartres have been

[205] Weidlein and Hamor 1936 *Glances at Industrial Research,* 169
[206] Ibid.

erected, unaided, by the nobles of Beauce. The best science, like the greatest art, belongs to the people and must express their spirit. The treasure found by the individual is worthless until it is brought into the open to be shared." [207]

This language combines a sort of flowery idealism portraying science as a human art form for everyone, while also recognizing its power with nearly militant fervor. These advancements in science and technology "have forcibly impressed on everyone the concrete significance of science to his own welfare." In this statement, the concept of "welfare"- a word that as used in this context strategically combines a rich mix of connotations of aid, protection, safety, and wellbeing - contributed to an overall message of significance and gravity. Perhaps this is unsurprising since the technologies that Weidlein and Hamor cite as influential for the time, "such as radioactivity, the automobile, the airplane, the radio, the X-ray – all of them the results of scientific research," had both civilian and military applications.[208] In this context, the popularization of science was not only deemed important as an educational goal in its own right, but also as part of a broader strategy for long term economic growth and national stability, both linked to technological change.

The work produced by Mellon Institute's leaders conveyed the challenge of representing techno-scientific development as a practice fostering hopefulness for a brighter future while simultaneously presenting this type of work as one of dire necessity. Duncan proclaimed that his work as an "interpreter of science" stemmed from his own, "intense conviction that only through the application of modern science to industry will there ever come into the world an era of gracious living."[209] This idea of

[207] Ibid.
[208] Ibid.
[209] Duncan, *The Chemistry of Commerce,* xii

progress envisioned an achievable future built upon well-coordinated systems to link science and business creating a higher standard of living. While Duncan often employed this narrative strategy, meant to inspire and delight with an idealized vision of a techno-scientific future, it was also tempered with competitive zeal. He wrote in 1905 in the preface to his first book, *The New Knowledge*, "there is something peculiarly attractive about this borderline between science and ignorance."[210] He challenged his reader to engage with the book and approach this "fighting-line – [where] it is so pre-eminently human and natural to love the spectacle of a struggle. It is the spectacle of temporary struggle that the author places before the reader, the *casus belli* being neither more nor less than the nature of the chemist's atom."[211] In a sense, Duncan was inviting his reader to not only join him for an armchair view of this "spectacle of struggle" that was familiar to scientists, but also to engage in their own internal sparring match, without needing to venture far from the comfort home.

Duncan described one of his goals as linking the abstract processes of science to the real world and, in turn, to the mobilization of applied science for an improved standard of living. Rather than dwelling on the abstract "romantic interest attached to radioactivity and the nature of the chemist's atom," he asserted that his type of book about the applied and industrial sciences "possesses the glorious interest that attaches to the doing of real things."[212] Duncan acknowledged that his role was one of responsibility as a science communicator during a time when "the great expositors are dead, Huxley and Tyndall and all the others; and the great expositor of the future, the

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Perhaps today we would call Duncan a science writer, however I did not come across this term in any of my sources. Rather, this role is more often described as that of an "interpreter of science," someone with a science background (unlike most journalists at the time) who also had the ability to communicate to an audience outside of the scientific community.

[210] Duncan, *The New Knowledge*, xvi

[211] Ibid.

[212] Duncan, *The Chemistry of Commerce*, xii

interpreter of knowledge to the people, has still to be born." With a flair for the dramatic, Duncan claims that he "falls under the burden of these difficult conditions. He dares venture the undertaking only because of the need of some interpretation of this new and interesting knowledge and because of his own sincerity."[213]

He saw the world as "divided between men who know and cannot tell, and men who tell and cannot know."[214] He characterized available sources for "laymen in science who wish to follow the trend of modern discovery" [215] as limited to either "pseudo-science of the magazines, which is arranged chiefly for dramatic effect rather than accurate exposition…or specialized and technical works written by the discoverers themselves for their fellow-workers."[216] The latter required technical training and "the lay reader, however cultured and thoughtful he may be, becomes utterly and hopelessly lost." [217] Duncan assumed his readership had only a high school education, but he especially wrote for an audience with a "love for contemporary natural knowledge." [218]

Duncan shared a keen interest in narrative with his younger brother Norman Duncan (1871-1916), a professional writer and close ally, who no doubt influenced his work as a science communicator. The brothers managed to stay in close proximity throughout their careers, serving on the faculty together (Norman in literature and Robert in chemistry), both at Washington and Jefferson College in Pennsylvania, and then at the University of Kansas. Both were actively publishing during the same period in magazines and longer book-length forms. Norman wrote seventeen novels and short stories between 1900 and 1915 and was a regular contributor to popular magazines

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[213] Duncan, *The New Knowledge*, xvi
[214] Duncan, *The New Knowledge*, xv
[215] Ibid.
[216] Ibid.
[217] Ibid.
[218] Duncan, *The New Knowledge*, xvi

(*Atlantic Monthly, The Century, The Outlook, McClure's Magazine*). They traveled abroad as contributors to *Harper's Monthly*; Robert went to France and Germany, while Norman served as a foreign correspondent in the Middle East, Southeast Asia and Australia.[219] The Duncan brothers, prolific writers in their early careers, both died in their mid-forties within two years of each other.

In many ways, the early and untimely death of Robert Kennedy Duncan, just as the Mellon Institute (then titled Mellon Institute of Specific Industries) was erecting its first permanent home, only served to bolster the power of his narrative. The RKD Club was soon founded in his honor to bring together the Fellows from across the Institute. They hosted lectures on professional topics as well as social events. Although these young fellows wouldn't have the chance to meet Duncan, they could still feel like a part of the legacy of "his boys."[220] Nearly all descriptions of this then young Institute began with some version of an origin story that included Duncan's legacy as a writer and originator of the fellowship program.

Indeed, scientific narratives of progress were also major products of the Mellon Institute. These stories complemented the research output including new products and process improvements for companies and trade associations as well as their own independent research. Weidlein and Hamor, administrative leaders and chemists who started their careers with Duncan, followed in his footsteps by writing works together that were aimed at non-academic audiences to promote scientific research and development. They especially highlighted the relationship of chemically based industrial applications to everyday quality of life in the United States. Weidlein and

[219] Norman Duncan's destinations; 1907-08 Syria, Palestine, Arabia, Egypt, 1912-13 Australia, New Guinea, Dutch East Indies, the Malay States in Carnegie Mellon University Archives, Mellon Instiute Records, Box 205 ff7497

[220] This was a common way that Duncan addressed the Fellows.

Hamor collaborated on two volumes, *Science in Action – A sketch of the Value of Scientific Research in American Industries (1931)*, and *Glances at Industrial Research During Walks and Talks in Mellon Institute (1936)*.

These books not only chronicled the scope of the current work being conducted at Mellon Institute for Industrial Research, but also placed this chronicle into a broader survey of American industrial science and made a case for the importance of the industrial research enterprise in general. Weidlein and Hamor's 1931 book, *Science in Action – A sketch of the Value of Scientific Research in American Industries (1931)*, made a general case for the role and impact of industrial research in the American economy as a whole, and highlighted the work of the authors' own particular institution. They presented a generalized profile of American industrial science with the Mellon Institute itself serving as one of many examples, including the Battelle Memorial Institute in Columbus Ohio, as well as corporate laboratories such as Bell Telephone Laboratories and General Electric, and trade associations. The second book, *Glances at Industrial Research During Walks and Talks in Mellon Institute*, takes a more allegorical approach, using Ancient Greek mythology to discuss industrial science and with an increased emphasis on the Mellon Institute as a way to foster legitimacy through connection to a "timeless" classical narrative. This second book-length work reflected a desire to increase both awareness and importance of industrial science for a popular audience through literary imagery that links classical myths of heroism with contemporary scientific endeavors.

The earlier1931 volume was drawn from the previous fifteen years of non-technical science communication including articles and speeches delivered to bankers, manufacturers and businessmen. It is worth noting that the public that Weidlein and

Hamor imagine, although still predominantly male, differs quite a bit from Duncan's. While of course Duncan's 'general audience,' included industrialists like E. Ray Speare and even the Mellons, he explicitly addressed both teachers and students at the high school and college level. Weidlein and Hamor addressed a general audience who might not have had much knowledge of science but would have had some business experience. *Science in Action* might be read as a report on the state of the art of industrial science with chapters such as "The Past and Present Condition of Industrial Research," "Scientific Management and Rationalization," and "Industrial-Research Methods and Men." However, *Glances at Industrial Research,* published five years later in 1936 takes a dramatic approach to not only reporting on the state of the art but also fostering legitimacy for industrial science.

Weidlein and Hamor began *Glances at Industrial Research,* with a consciously crafted analogy between industrial research and the myth of Jason and the Argonauts. Throughout the work they mix imagery from classical sources with contemporary examples from industrial science. Their narrative strategy thus cast researchers as contemporary epic heroes who quest to bring golden fleeces in the form of new materials to society at large through their goal-oriented research and teamwork. However, they also go one step farther with this analogy to assert, "In its research achievements our industrial science surpasses the miracles of mythology, of the days of Jason, all of whose science was poetry."[221] Although their strategy was to engage the imagination through heroic legends, Weidlein and Hamor were clear about the products of industrial science which were concrete, neither fantastical nor speculative. Indeed, they even recast the Greek fates into a benevolent industrial context.

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[221] Weidlein and Hamor, *Glances at Industrial Research,* 13

"The poetic concept of the Fates as the arbiters of men's lives has its present day analogue in the more benign forces that direct industrial progress. They made life so unsatisfactory that the stages held no man fortunate until he had died; but the various types of scientific research, the modern Fates of industry, strive to make men more happy and prosperous. Clotho, who in mythology, began the thread of life by putting the wool around the spindle, is now basic production research, or the industrial research that reveals new products and new processes. Lachesis, who fixed the length, has been replaced by plant research, which directs manufacturing-scale development. Instead of the gloomy Atropos, who cut the thread, we have a brighter figure, merchandizing research, to show men how they are wasting effort and resource on obsolete commodities and to lead their attention to those more profitable."[222]

This appropriation of a classical myth into a new context of industrial production served several purposes in the refinement of Weidlein and Hamor's narrative of progress. It helped to create a connection between the contemporary endeavors of scientists in industrial research and an ancient, or even "timeless" past. The use of the three fates as the machinery of industrial production also gave this field significance of epic proportion by comparing industrial research to the very mechanisms that governed the trajectory of humanity as a whole. Furthermore, this metaphor thus emboldened researchers, transforming them into agents of change, as the designers of industrial systems, able to shape the outcome of fate itself.

For the Mellon Institute's science communicators -- Duncan, Weidlein and Hamor -- human progress was fundamentally linked to the mobilization of new scientific knowledge to address industrial problems such as waste minimization and creation of new materials and processes, through the efficiently coordinated efforts of technically minded managers and academic laboratories.[223] The notion of progress was closely linked to science as an organizing framework that cut across society including the economic and political spheres. In the chapter on "The Groundwork of Industrial

[222] Weidlein and Hamor, *Glances at Industrial Research,* 41
[223] *Science and Human Progress* served as the title for the 50^{th} anniversary publication and celebratory theme for the Mellon Institute for Industrial Research.

Research," which began *Science in Action*, Weidlein and Hamor presented a series of questions that linked science and society. They asked, "Why has it become so difficult without a knowledge of science, to do many things or to understand many things that are happening in finance, industry, and commerce, and even in diplomacy and politics?"[224] For Weidlein and Hamor, an interest in "this ever-present science" was not only an important component of contemporary knowledge, "which so many leaders in business cherish" but a key to understanding and acting in the powerful arenas of business and politics.

Proponents of industrial and educational facilities and scientists were not the only groups pushing for an increase in general awareness about the chemical industry. Indeed, in a front page article entitled, "The Skeleton in the Laboratory," published in 1929 in the trade journal *Chemical Markets*, editors called for "technical papers [to] please copy" their desire for an "education campaign to sell the science of chemistry and the idea of the chemical industry."[225] However, unlike the science-centered perspective found in work like Duncan's, which urged industrialists to embrace scientific research, this journal, geared toward businesspeople in the chemically related industries, made a different plea for "better mutual understanding" between science and business. Almost twenty-five years after Duncan was publishing and attracting the interest of industrialists like Speare and the Mellons, this article written for the chemical executive of the late 1920s described this group as "the poor tired businessman…bombarded with statistics and pelted with allegories." [226] As they looked for their longer-term investments in scientific solutions to remedy the more immediate problems of their balance sheets during an increasingly uncertain economic climate, many of the readers

[224] Weidlein and Hamor, *Glances at Industrial Research*, 3
[225] Chemical Markets June 1929 Vol XXIV no 6 pg 583
[226] Ibid.

of *Chemical Markets* would have identified with this characterization This article described the persuasive narrative of chemical investment as one of coercion rather than inspiration, "threats of bankruptcy have [been] held over his head, and before his nose have been dangled promises of profits. Varying degrees of adroitness, fiction, fact, and fable have been employed in this good cause of selling chemistry to the executive." [227] Chemists were acknowledged as a now integrated piece of the industrial enterprise, "A chemist is no longer considered a pleasant sort of luxury like a bed of geraniums in the factory yard." [228] However, to the chemical executive, they were also, "a sort of necessary evil, like advertising or the trade association." [229] This "skeleton" that the article addressed, was in part a "comprehension of chemical problems," an understanding that could take into consideration both the science of chemical processes and the economic context. Although "...the skeleton has been driven out of the director's room and the private offices[,] It lurks still in college halls and laboratories." [230] From the point of view of the chemical executive, both "chemists and the teachers of chemists know little of the practical economic problems of the industry which puts their science to work for the benefit of mankind, which offers the one employment and which raises endowments for the other." [231] This statement expressed both acknowledgement of the importance of applied science to industrial success, as well as the increasingly burdensome financial role that the chemical industry played in the educational enterprise. However, there is a lingering sense of weariness and disillusionment also associated with long term chemical investments that have not yet produced the economic transformation that was promised at their inception.

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[227] Ibid.
[228] Ibid.
[229] Ibid.
[230] Ibid.
[231] Ibid.

This increased skepticism about the sustained costs of long term investment in chemical research echoed within the business community. As chemical research became a more integrated part of the industrial system in the United States, there were fewer opportunities for profits associated with drastic efficiency improvements. In his 1930 article, "What do we Expect of the Chemist?" published in *Chemical Markets*, Walter S. Landis, vice-president at American Cyanamid, lamented, "in highly developed processes, such as we have in the chemical industry to-day, when a chemist changes some factor in the process, the savings are modest."[232] A metallurgical engineer himself, former professor at Lehigh University, who had joined American Cyanamid as chief technologist, Landis had a well integrated knowledge of the challenges of industrial chemical research from both the academic and business perspective.[233] Since "ninety percent of the chemist's work is destructive of capital" when focused on process improvements, he urged the chemist to "cultivate a broader idea of his purpose and work." This meant looking beyond process efficiency in the use of raw materials and toward the development of new uses for products. Landis drew attention to the omnipresence of the chemical field: "there is no single activity in which chemistry does not play a part. It is at the bottom of everything, entering into food, shelter and clothing."[234] Yet, he scolded the chemist for "the general aloofness which exists towards himself and towards chemistry," and urged him to "remove the veils of mystery and secrecy which surround chemistry, so that the science, and the industry based upon it, may secure a better reception from the public and from other business[es] and industry[ies]."[235]

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[232] Walter S. Landis "What do we Expect of the Chemist?" *Chemical Markets* XXVI, 4 (April 1930): 359
[233] http://www.electrochem.org/dl/hc/presidents/landis.htm accessed 05/05/2014
[234] Landis, 360
[235] Ibid.

Both the high speed of change following World War I and the shroud of mystery often associated with the chemical industry and its proprietary processes began to elicit suspicions rather than inspire confidence in industry in the popular imagination. "Chemical operations, always mysterious to the layman, have roused his suspicion, and the notion that chemical progress is a dangerous destroyer of values has of late spread widely," reported the editors of *Chemical Markets* in 1931. However, they embraced the destructive nature of change as a central component of their idea of what progress meant to leaders in the chemical industry.

> "All progress is destructive. Every improvement means a replacement. The destruction of the indigo plantations by the synthetic dyestuff is only a little more dramatic, because of its speedy accomplishment, than the banishment of the horse from our city streets or the passing of clipper ships from the high seas. Moreover, there is almost always a curious compensation in chemical improvements, a transfer of values, a change in uses."[236]

This idea of progress, a concept which, by its very nature, is rooted in perpetual change, was difficult for industrial leaders to fully sell to the general public (however they might have envisioned them) and perhaps to themselves as well.

While the writings of Duncan, Weidlein and Hamor shared a unifying theme, the promotion of industrial research and the enterprise of science as a whole, they did not converge on a singular definitive narrative of progress. Rather, when treated together as a body of work, the writings reveal that their portrayal of progress adapts to changing economic and political conditions. In his first book, *The New Knowledge (1905)*, Duncan, the pioneer, aimed to bring the public into the contemporary discourse surrounding recent developments in science. His next project focused more explicitly

[236] "Compensating Changes" (front editorial summary) *Chemical Markets* (March 1931): 243

on industrial science, expressed as articles in *Harper's Monthly* and the book-length version of this material *The Chemistry of Commerce (1907).* Here he used the tangible aims of the industrial world as a bridge to the scientific processes embedded in everyday experience. This book is more persuasive in nature than the first. After establishing scientific authority in *The New Knowledge*, and successfully piloting the Fellowship System at University of Kansas, Duncan then proceeded to make his case for closer collaboration between science and industry. Duncan's third and final book, *Some Chemical Problems of Today* (1911) blended the style of both of his previous works. In his first chapter, "The Prizes of Chemistry," Duncan made his now familiar plea to chemists to take up the diverse, pressing, and potentially lucrative problems of the industrial sector. He then quickly shifted to a series of chapters with a more strictly chemical focus beginning with a chapter on "The Question of the Atom." Finally he profiled particular industrial scenarios with examples from bread and camphor, and ended with a section on the industrial fellowship system.

Weidlein and Hamor's books followed a parallel strategy. Their first book, *Science in Action (1931)*, published fifteen years after the founding of the Mellon Institute and Duncan's death, is an artifact of a quite different time for industrial science. They also began, however, with a work that is primarily a survey of the state of the art, though they focus on contemporary developments in industrial science as opposed to fundamental research. The over-twenty-year gap between Duncan's last book and Weidlein and Hamor's first spans change not only in the immediate context of the Mellon Institute, but also in the greater world including World War I and the onset of the great depression. *Glances at Industrial Research (1936)*, also reflects these changes – industrial science is no longer a new phenomenon in need of introduction, but rather a well-integrated and costly part of the industrial system in need of increased legitimacy. This second book, more persuasive and romantic in tone, drew upon a renewed connection to fundamental science and classical mythology to give industrial science and the Mellon Institute a feeling of longer history and more permanent significance. In each book sequence, the specific content may have changed, yet the authors' created the same general narrative movement asserting their own agendas and institutional chronicles into a broader field of science communication.

Although textual narratives in the form of book-length works aimed at broad audiences were not among the products of MIT's early leaders, they, too, crafted their own kinds of narratives of progress that traveled beyond their institutional walls. MIT's leaders often gave public addresses on the national stage as representatives of the disciplines of science and engineering and the enterprise of higher education in addition to their own home institution. For example MIT's president, Karl T. Compton was invited to speak on behalf of scientific research before the National Industrial Conference Board (NICB), and the American public listening via radio, at their annual meeting themed on "Social Progress" in 1936. The NICB was comprised of American business leaders from a diverse sample of industries who engaged major social and economic issues, especially as they related to labor and productivity. This organization was founded in 1916 by eleven of the major American trade associations to address the industrial turmoil surrounding the First World War.[237] John H. Hammond, chairman,

[237] The Hagley Museum and Library holds the complete transcripts (1916-1985) for the National Industrial Conference Board (NICB), which was later renamed The Conference Board in 1970. These are an excellent resource for putting social and economic issues into context of the business community. These records include meetings that were broadcast over the radio as well as more private meetings. Unlike the more common forms of meeting records such as minute summaries and agendas, these transcripts provide insight through actual conversation. A brief historical background for the NICB is included with the online finding aid at http://findingaids.hagley.org/xtf/view?docId=ead/1057.xml Accessed May, 14, 2014

described the NICB as "the central cooperative institution of scientific research and education for the improvement of American industrial enterprise."[238] This organization was devoted to both understanding and strengthening American industry, a service that Hammond characterized as "impartial and non-partisan in spirit, but never indifferent or neutral in purpose." The Board not surprisingly produced narrative, in addition to statistically focused reports.[239]

Compton's remarks, offered as one of two invited talks to be broadcast over a national radio network, led off the conference on "the American program for social progress." The other speakers all linked their topics to American conceptions of freedom as addressed through the roles of religion, business, government and the state, and education. The presentation of these themes were framed in conscious opposition to what Hammond described as "the process of social retrogression that is observed in Europe today," referring specifically to the situations in Fascist Italy and Nazi Germany. In this international climate of unrest and uncertainty overseas, the implications of Compton's narrative of scientific progress that included many of the desired rewards of empire, yet without the often-associated conflict, would not have gone unnoticed by American listeners.

Compton connected developments in science to improvements on all aspects of quality of life, opening his speech with an excerpt from a resolution adopted by the American Association for Advancement of Science, submitted to the President of the United States in 1934,

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National Industrial Conference Board (NICB) records (Accession 1057), Hagley Museum and Library, Wilmington, DE 19807
[238] Twentieth Annual Meeting of the NICB May 28, 1936, National Industrial Conference Board (NICB) records (Accession 1057), Hagley Museum and Library, Wilmington, DE 19807
[239] Twentieth Annual Meeting of the NICB May 28, 1936, National Industrial Conference Board (NICB) records (Accession 1057), Hagley Museum and Library, Wilmington, DE 19807

> "WHEREAS, Development and application of science have been basic to the economic and social progress of nations, making possible such movements as universal education, abolition of child labor and slavery, emancipation of women, insurance and pensions, moderate hours of labor and great improvement in the standards of health, comfort and satisfaction in living;"[240]

He tied broad social developments such as the emancipation of slaves and women to discrete factors such as the creation of insurance and pensions, and went on to assert "our national health, prosperity, pleasure, and indeed our very existence, depend largely on science for their maintenance and their future development." For Compton science was the democratic answer to humanity's age-old desire for territorial expansion and increased wealth, previously the domain of imperialism and its "plunder and taxation of conquered nations and by 'labor-saving' production through the work of enslaved peoples." Instead of grounding the story of contemporary science in a classical past like Weidlein and Hamor, he instead tries to break ties with history. Compton, conflating a long historical past, rejected the conquests of the Egyptians, Greeks, Romans, along with the British East India Company, in favor of the image of the American pioneer. He painted the current state of American resources as not only finite, but reaching their saturation point. "We have come to the end of free expansion by migration westward, and of free exploitation of ever newly discovered resources of soil and minerals." The answer to this conundrum was not the American "geographical pioneer" hero of the previous century, but the "scientific pioneer, whose thrill of discovery or urge for reward is no less keen and whose fields of exploration are probably unlimited." Compton stressed, "further increase in our wealth, population, physical comfort and cultural opportunity will depend not on discovering new resources by geographical exploration but by wiser use of the resources we now have, through scientific exploration."

[240] Twentieth Annual Meeting of the NICB May 28, 1936, National Industrial Conference Board (NICB) records (Accession 1057), Hagley Museum and Library, Wilmington, DE 19807

Unsurprisingly, the fate of Native Americans was left out of Compton's characterization of "free expansion." Nevertheless, this omission served to create an even more vivid concept of an unexplored scientific frontier, which could be seized with intellect alone and without the familiar bloodshed of conquest.

For Compton, Duncan, Weidlein, Hamor, science and its applications were tools by which humanity as a whole (though most importantly in the United States) might save itself from its own shortcomings. The link between contemporary science and the long history of humanity was a factor that could be adapted to fit the particular strategic necessity at hand. For Weidlein and Hamor, it was important to establish a connection for the relatively new field of industrial science to a classical past to foster legitimacy, whereas for Compton, a break with the injustices of the past in favor of a clean slate for American scientist-explorers helped to separate his idea of progress from the growing conflict in Europe. The challenge of striking a strategic balance between the constant and dynamic process of creating change, and the long term stability that might be achieved for humanity through science, was reflected not only in the words of Mellon and MIT's leaders, but also through their built environment, as we discuss in the section that follows.

BUILDING SPACES FOR INNOVATION

Text is only one method for creating shared stories that shape and reinforce institutional culture. The built environment, whether manifested in large-scale architectural plans, small details in functional equipment, or aesthetic ornamentation, may also convey its own narratives of progress. In this section, I employ the built environment at both MIT and Mellon Institute to highlight the material dimensions of their research and educational programs in both symbol and practice. I employ two different methods to understand these built environments as artifacts. In the case of MIT, I treat the contemporary buildings as a living archive, a tool for adding an additional perspective to my early 20th century story. I approach the Mellon Institute, on the other hand, from a more traditional historical perspective using documents and photographs that describe the "New Building" when it opened in 1936. It is not my intention to promote either of these methods in particular, but to offer them together as complementary tools for perspective making.

As I studied the textile research program in the early 20th century through its extant records in the MIT archives, I also explored the contemporary campus for traces of this now disbanded laboratory. From this standpoint, I was treating the MIT campus itself as a living archive. Unlike a library archive, which seeks to preserve and organize documents and other materials for future researchers in a rarefied setting, a living archive in the form of a building or landscape is subject to the changes of the world at large. After all, though it may contain elements from the past, it is an integral part of the present as well.

The section of the MIT campus that opened in 1916, commonly called the 'main group' may appear unchanged when viewed from the outside. A cohesive compound of interconnected buildings, crowned with the names of famous scientists, overlooks the Charles River and beyond it the city of Boston. Within these walls, the famed 'infinite corridor,' acts as its "spinal cord," a long hallway that connects five of the buildings in the 'main group.'[241] Today, walking through these contiguous buildings, which were designed by William Bosworth nearly a century ago, you may notice that all these

[241] "The Infinite Corridor is MIT's spinal cord. Many of our departments, classrooms, and labs radiate from here." MIT Virtual Tour http://web.mit.edu/vrtour/n2_index.html accessed April 10, 2012

building sections have numbers rather than names.[242] Indeed, nearly everything at MIT seems to have a number, from buildings to departments and individual classes. It gives a feeling of engineered logic to what may often be equally classified as happenstance.

Two floors above this usually bustling corridor, in Building 3, not far from the vaulted chamber of Lobby 7 and directly above the offices of MIT's senior leadership, is room 3-315. You can't quite see inside room 3-315. The double doors have frosted safety glass windows and are partially covered by posters. Black lettering on the window, worn a bit at the edges, labels this the "Charles T Main Textile Research Laboratory."[243] This room may seem like any other lab space, between a 3-D Optics Lab and Bimolecular Circuits Lab belonging to the Department of Mechanical Engineering. However, despite this label, there is no formal textile research program at MIT anymore. This program, once a course of study at both the undergraduate and graduate level in the 1910's, was finally renamed the Fibers and Polymers Lab before being formally discontinued in the 1990s. Textile related work at contemporary MIT is found distributed across the campus from Aero-Astro to the Media Lab. However, the current research that spun out of this original division and inhabits this laboratory today is in biomaterials, particularly tissue engineering.

Suspended in the stairwell facing this biomaterials laboratory with the obsolete label is a giant aluminum sculpture designed by graduate students in architecture, "a shimmering conduit designed to inspire delight, wonder and communication between

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[242] For an extensive discourse on the design and planning process of the 1916 campus see: Mark Jarzombek, *Designing MIT* (Northeastern University Press, 2004).
[243] This room was relabeled the "Laboratory For Regenerative Biomaterials" shortly after I began writing about the former textile laboratory in 2012.

the floors."[244] Not unlike a tissue scaffold at monumental scale, reminiscent of fishing net or sci-fi wormhole, this structure bends gracefully with gravity toward the infinite corridor below. A short walk down the hall from the labs there are offices for faculty in the program for History, Theory and Criticism of Architecture and the Cheney Room, a lounge exclusively for the use of female students. This contemporary juxtaposition of rooms and art along the hallway gives a feeling of planned interdisciplinarity to this patchwork, pieced perhaps more by changing physical rather than intellectual jurisdictions of departments.

In its current state, 3-315 and its program may be characterized as simultaneously a relic of discontinued scientific research as well as a place for innovation in a transformed discipline. On a campus that seems to be constantly under construction, one may wonder if the remaining historic label on room 3-315 was an oversight, or a tribute, or perhaps even a bit of both. Here, the physical placement of the former textile research lab, at the intersection of buildings 3 and 7, one floor above the offices of MIT's senior leadership and corporation, helps to highlight the often strained relationship between constancy and change, disciplinary and organizational structures at a place of higher education and research. This physical placement serves to echo the discourse surrounding the place of textile research at MIT described in the preceding chapter. This manifestation of the built environment as simultaneously an ad hoc patchwork, while also a formalized coherent whole, could be viewed as reminiscent of

[244] ***Dis(Course)4***, by Craig Boney, James Coleman and Andrew Manto, graduate students in the Department of Architecture (Course 4), located in the stairwell of Building 3, installed April 2011 "A stairwell transformed by a shimmering conduit designed to inspire delight, wonder and communication between the floors. Both airy and robust, the piece is created by hundreds of components cut by water jet from thin aluminum flashing and fastened to their neighbors by thousands of zip ties. Thin steel cables spiral down through the components along the diagonals of the regulating hexagonal grid to form an internal diagrid that gives the system additional strength. The result is a light-catching, attention-grabbing demonstration of student imagination and ingenuity." http://arts.mit.edu/fast/fast-light/fast-installation-discourse4/ Accessed 4/10/2012

the process of aggregation of industrial activities initiated by the Tech Plan. This somewhat awkward position at contemporary MIT in this corridor of architecture, arts, science, engineering, gender and administration may not seem too far in sentiment from the original laboratory' placement at the disciplinary boundaries of chemistry, physics and mechanical engineering, as well as its role between the academic and industrial nearly a century earlier. In this respect, the contemporary built environment as living archive echoes its historic origins with its own type of physical narrative told through space.

Indeed MIT historian of architecture and professor, Mark Jarzombek calls attention to the story of disciplinary tension and coordination in the construction of the building itself, which goes unnoticed to an untrained observer. Inherent within the buildings themselves was a combination of old style and new technology. Jarzombek characterizes proponents of the dominant Beaux-Arts style, as "entrenched in academe" and "slow to adopt technological improvements." Despite perhaps being interested in new building technologies, architects at the time were also under pressure to create works that could "express a reassuring continuity with the past." Although the new construction techniques in steel and concrete and the Beaux-Arts style were both popular topics among architects at the time, they represented different branches of the discipline. Jarzombek notes that considering these differences in approach to architecture, their "seamless integration in the MIT building, although largely unnoted, was remarkable."[245]

Of course, the timeframe makes a difference in not only how an outside researcher may read this physical narrative in retrospect, but also how its inhabitants

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[245] Jarzombek 81-83

might view their own role and story within this space. Perhaps the original configuration for the placement of the textile laboratory when the MIT's Cambridge complex was new in 1916 would have appeared to be an entirely straightforward and unambiguous configuration to its contemporaries. Indeed, there is a different spirit to a place that has just opened its doors, specially designed for a very specific and cohesive purpose. This was the case for the Mellon Institute's "New Building," which opened with a great deal of ceremony in 1937. It was a striking coincidence that construction began on the "New Building" concurrent with the publication of *Science in Action.* Furthermore, *Glances at Industrial Research* was released just before the completed "New Building" was officially revealed. In many ways this structure, a state of the art laboratory building also embedded with symbolic design features, was a physical representation of the narratives of progress so passionately described by the text of its leaders.

The "New Building" was the fourth and final Mellon Institute building. As the organization grew and gained notoriety, this scale was reflected in both space and materials. The first building was a two-story structure constructed from wood. Duncan and Whittle, who had previously been the only Pittsburgh-based staff, moved there in 1911 with five additional secretarial staff members. They had previously occupied a temporary attic office in Duncan's home. With the formal transfer of the fellowship system from Kansas to Pittsburgh, the wooden building was moved to the end of the street, and work began on "the first permanent building" in its place. This brick and stone building opened in 1915 at the intersection of Thackeray and O'Hara Streets, a five-story neoclassical structure with four Doric columns and pediment above the entrance.[246][247] A pre-existing brick building was moved across the street to accept the overflow of work from the "the first permanent building." On this newly vacant lot, construction began on the "New Building." This "commodious modern structure" on the corner of Fifth and Bellefield Avenues lined with sixty-two elegant yet undeniably substantial Ionic columns that spanned the entire perimeter of the building face. This "plain but massive" building was designed to cultivate an ever-changing body of scientific work humming within its walls shielded within a facade of immovable weight.[248]

Originally planned for completion by 1932, construction continued through the economic crisis of the early 1930s despite the "state of commercial dullness ... [which] had a profound effect upon industrial research in general."[249] The first use of the building in 1934 was as a showplace rather than a laboratory center, before the facilities were complete. As part of the Pittsburgh meeting of the American Association for the Advancement of Science a Science Exhibition held there attracted over 25,000 visitors within the course of four days.[250] The facility was inhabited gradually over the course of the following two years and was fully occupied by the spring of 1937.[251]

Just as the workings of the fellowship system and even Whittle's filing mechanism had been explained in detail in publications in specialized journals, so was

[246] "Lois Whittle to Rena Zeffer April 12, 1962"
[247] W.A. Hamor, "Description of the new Building of the Mellon Institute" WA Hamor *Journal of Industrial and Engineering Chemistry* Vol 7 No 4 (April 1915): 333
[248] "The Activities of the Mellon Institute during 1930-1931" *Journal of Industrial and Engineering Chemistry,* Vol 9 No 7 (April 10, 1931): 107.
Each monolithic column was 36.5 feet tall, 6 feet in diameter and weighed 60 tons. H.S. Coleman "Planning and Equipping Laboratories for Research," *The American School and University* 1938
[249] "The Activities of Mellon Institute during 1932-33 Industrial Research in the Present Economic Crisis" *Industrial and Engineering Chemistry* Vol 11 (April 1933): 124
[250] "Progress at Mellon Institute during 1934-35" *Industrial and Engineering Chemistry* Vol 13(April 1935): 162.
[251] "Research Progress at Mellon Institute during 1936-37" *Industrial and Engineering Chemistry* Vol 15 (April 1937): 143.

the design and function of the "New Building." Harry S. Coleman, assistant director, wrote in extensive detail about the design of the laboratory spaces from the physical layout to the custom construction of cabinets and choices of materials. Even in an article which was meant to focus on construction and design issues, "Planning and Equipping Laboratory Research," he began with the familiar story of the founding of the Mellon Institute and the legacy of Robert Kennedy Duncan and his popular writing. For Coleman, addressing "specialists who are concerned in science education, laboratory layout and equipment, and laboratory maintenance or management," it was impossible to talk about the design of the building without some grounding in its functions and people. His style was clear and concise as he listed the three major functions of the Institute as "a station for investigation in pure and applied sciences...a school for training research workers through practical experience in investigational methods...[and] a clearinghouse of technical information for the professions and public."[252]

When viewed from above, the building looks like a hollow trapezoid divided into four sections by a cross. The outside facing sections are nine-stories high and the internal cross-wings consist of four floors with 1,115 court-facing windows. The bottom two floors are actually underground, though they also receive natural light "because of the use of light courts, which extend down to the first floor level." The executive offices, general office and library were on the main, or fourth floor. Below the main floor were three lower floors containing service departments, the auditorium, and the sections for large-scale experimentation. The research laboratories occupied the

[252] H.S. Coleman "Planning and Equipping Laboratories for Research," *The American School and University* (1938)

remaining upper floors (fifth through eighth), while the ventilating apparatus took up the majority of the attic.[253]

To achieve their goals of "flexibility, simplicity and utility" in the laboratory spaces, it was not possible to use ready-made laboratory and office furniture. Coleman described the "considerable original development" that was needed to create the type of environment that they had envisioned along with specialized contractors.[254] Everything from the "Alberene" stone tabletops that covered the custom-designed cabinetry, to adjustable die-cast aluminum shelf brackets, drawer pulls and cabinet knobs were treated with meticulous attention. The extensive wiring system, also designed for flexibility and providing multiple types of current and easily replaced receptacles, was also featured in its own article.[255]

The physical environment played a role in the rebranding of the Mellon Institute in the 1950s to include a stronger emphasis on basic research in addition to their already well-known industrial work. Lest they go unnoticed, William Hamor described parts of the Institute that had been specifically designed to reflect the purpose of the organization, especially its "constantly increasing attention to fundamental researches" in a pamphlet "Symbolism in Mellon Institute," published in 1957. Hamor placed emphasis on three areas on the main floor that were designed to "render the art therein emblematic of the purpose of the institution," the main lobby, elevator doors, and library.[256] Not unlike the narrative strategy in *Glances at Industrial Research,* this

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[253] H.S. Coleman "Planning and Equipping Laboratories for Research," *The American School and University* 1938
[254] H.S. Coleman "Mellon Institute Research Laboratories," chapter in *Laboratory Design* (New York, NY: Reinhold Publishing Corporation, 1951)
[255] Wiring for Research: Pittsburgh's new Mellon Institute provides industrial scientists with an electrical system planned for laboratory service. *Electrical Contracting* 36, No 7 7-10, 45 (1937)
[256] W.A. Hamor "Symbolism in Mellon Institute," 1957, in Carnegie Mellon University Archives Mellon Institute Records Box 123 ff4005,

discussion of symbolism also begins with Greek mythology. The creation of scientific knowledge was depicted as a bas-relief of the birth of Athena from the head of Zeus. Hephaestus, god of metallurgy, is a central actor in this story since it was he who cleaved Zeus' head with his ax to reveal Athena. "He is representative not only of artifice and invention but also of the industries in general and of their contributory part in the Institute's researches in quest of new scientific knowledge." [257]

"The rise of chemistry" was conveyed through alchemical symbols on the elevator doors through which people could literally ascend daily. Inscriptions from famous quotes accompanied the light pedestals, the "four torches of science that illuminate the way for advancement, namely, nature, truth, education and peace." [258] Hamor presented "an important dogma of science" through the words of Goethe, "the first and the last thing required of genius is the love of truth." He considered truth to be an important aid to progress, as they both "travel together in the same direction on the firm ground of science." Through this idea of "love of truth," which was "more important than truth itself" and "lights the path of duty...the indispensible guide for all research, both pure and industrial," Hamor sought to reinforce values of "intellectual honesty, thoroughness, accuracy, freedom from prejudice, and open-mindedness." [259]

In addition to this now familiar use of the classical world to infuse the present with a sense of heritage, nature also played a central role in the crafting of symbols in service of science. The idea of nature was present throughout many types of work at the institute. In some cases, like the paper or food industry, naturally occurring organic matter served as a raw material. In other cases, imitation of a natural material would

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[257] W.A. Hamor "Symbolism in Mellon Institute," 1957, in Carnegie Mellon University Archives Mellon Institute Records Box 123 ff4005.
[258] Ibid.
[259] Ibid.

have served as an inspiration to create analogous synthetic products. Pesticides and fertilizers were also developed to promote the growth of plants. By aligning industrial science with the concept of nature as well as explicitly highlighting the links between this work and the natural world, the idea of chemical products as artificial or against nature could be downplayed.

Hamor's emphasis on symbols from the ancient world and nature may have served to instill a feeling of deep-rooted history and significance to the Mellon Institute. However, they also help to rebrand not only the place but also the practice of industrial science. When walking up the steps of the massive structure and through the towering columns and down clean marble halls, embellished with plants and ancient symbols wrought in stone and metal it would not be difficult to be taken in by the language of "truth" and "peace" that lined the walls. Perhaps it may even be difficult to conjure images of the noise and bustle of an industrial plant or the foreboding scent of chemical warfare. Indeed, "systematic symbolization usually has a practical end." This practical end of course may not be a singular notion, nor would it be the same for each person. Rather this combination of romance and art carefully placed in service of the Mellon Institute's work may remind a young scientist why science was worthwhile on a particularly frustrating day, inspire a secretary to find deeper purpose in the act of filing, or convince an industrialist that this was a place for substantial long term investment. Hamor believed that "effective original symbolic results are intrinsically emblematic of scientific forethought."[260] Though based on Hamor's contributions to the Mellon Institute, I may also add "managerial forethought" to his use of symbols.

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[260] Ibid.

Showcasing Industrial Progress

"Science in general has needed an interpreter to translate it into the terminology of the man on the street, and that is one of the greatest functions of industrial research."[261] This comment by Charles F. Kettering (1876-1958), head of research at General Motors from 1920 to 1947, characterized industrial science as a bridge between an abstract and often-inaccessible idea of science and the familiar landscape of the everyday. For example, through shared chemical concepts, an apparently familiar household item such as a textile or window could be used as a gateway to topics traditionally more removed from everyday experiences such as fossil fuel processing or mineral extraction. Indeed, it is this positioning of industrial science as a connection point between the apparently disparate domains of the theoretical and tangible, molecular scale and high volume production, local and global, science and business, which makes this field both fascinating and difficult to express simply.

Earlier in this dissertation, I have shown how this combination may be fraught with tension, yet may also find productive synergy. The textual works presented at the beginning of this chapter represent a particular type of passive public engagement. Whether presented as an article in a variety magazine, or a longer work in book form, the information, despite the author's intention, could be read in pieces, set aside and revisited, yet remain effective in communicating its message. An exhibit, on the other hand, while it may have the advantage of presenting real objects rather than photographs or descriptive text, needs to attract and keep the attention of its viewer in

[261] C.F. Kettering, republished in the "They Say" section which compiled recent comments made by related publications and prominent individuals. *Chemical Markets* February 1928. After 1929 this section was retitled as "Quotation Marks."

real time. This section presents narrative strategies and challenges associated with showcasing industrial science under a wide umbrella of general education through the strikingly contrasting venues of a public museum and a world's fair. Although the particular topics, such as the chemistry of new synthetic textiles, or tire production, may have been present across these venues, each institutional context comes with different challenges with respect to messaging and educational content. In this section, I argue that the act of showcasing industrial science through temporary exhibits helps us to understand the challenges presented by a topic that blends science and business in an educational setting, as well as the narrative power through experience to create modified interpretations of the present to make an imagined future seem more possible.

Along with the 1937 opening of the Mellon Institute's "New Building," itself a physical symbol of industrial progress, there were also exhibits on display designed to "illustrate the scientific and technologic aspects of the various problems under investigation" throughout the Institute for a general audience.[262] This effort, described by Weidlein as "an important feature of the dedication program," consisted of forty exhibits, each in its own booth, occupying the two lower floors of the building in the "spacious chemical engineering and unit plant sections."[263] These exhibits, open to all visitors, were designed by a Committee of the Fellows along with Dr. L.W. Bass, Assistant Director of the Institute, as executive adviser. As a series of displays conceived by members of the Mellon Institute research and administrative staff, these could be thought of as simultaneously an outward facing display as well as an internal reinforcement of institutional narrative.

[262] Carnegie Mellon University Archives Mellon Institute Records, Box 206 ff7610,
[263] Ibid.

One of the aspects that made industrial science a difficult concept to convey succinctly was the sheer variety of examples across fields that might not appear to have anything in common, aside from their link to chemical research. There were exhibits related to construction materials including ceramics, glass, paint, resins, and architectural marble, including a special section devoted to the materials used in the "New Building" itself. Hydrocarbons were also a popular theme with exhibits including; petroleum refining, carbon black and bone black, and by-products of coke technology. Medical-related work included both fundamental and industrial projects, including new organic materials with possible therapeutic effects, cause and prevention of dental carries, X-rays and spectrography, as well as contributions to the revision of the *United States Pharmacopoeia.* There were also many projects related to natural materials such as cork, cellulose products such as cotton, paper, and rayon, nutrition, and by-products of milk. Non-chemical industrial work such as merchandizing and manufacturing studies from topics ranging from meat to department stores were also on display. All of these booths were meant to contribute to "the underlying motives, being to illustrate in accurate yet popular style, the technological background of industrial researches now in progress and also recent scientific development in pure research fostered by Mellon Institute." [264]

The series of exhibits presented at the Mellon Institute, which showcased their own researchers' work and industrial applications within a newly designed and spacious home, created an unambiguous situation for display. Although the work was presented in an educational context, it was also intended to build enthusiasm for the particular projects carried out at the Mellon Institute both in fundamental science as well as those

[264] Ibid.

tied to corporate partners. For example, if a particular plate glass company had sponsored a project, it would not seem odd or unfair to include samples or processes from this corporation in the absence of its competitors. However, the exhibition of contemporary industrial science outside of its scientific or corporate home may face a different set of challenges both in terms of presentation strategy and access to materials.

Indeed, the practice of exhibiting the diversity of contemporary industrial science in a setting that was designed to educate the general public, yet without explicitly promoting commercial or research development presented considerable obstacles. There was a nearly overwhelming array of potential chemical artifacts, and to gain access to them it was necessary to have connections to the producing industries. A particularly vivid example of these challenges faced the struggling Section of Chemical Technology at the Smithsonian Institution in Washington, DC. This small department was created in 1923 within the US National Museum in the department of Arts and Industries, under the curator of textiles. The curious administrative placement of this section within several layers of materials-related fields, and the diversity of its collections and early work highlight the difficulty of categorizing and defining the scope of a field as diverse as "chemical technology."

Every material could be described through its chemical properties. This made the theme of chemical technology especially challenging for an organization devoted to collecting and exhibiting artifacts. After all, every object could potentially be considered for display. During its first year of operation, the section "took over the old collections of organic products," which included materials such as ivory and tortoise shell, described in the 1923 Annual Report as "very valuable since they represent industries which have ceased to operate or will be compelled to stop manufacturing in a few years because of increasing scarcity of the animals producing these raw products." Simultaneously they also "started new exhibits to illustrate modern chemical industries deriving their products from organic sources."[265] In addition to the wide breadth of artifacts under the care of this steadily growing collection, the bulk of the exhibition, registrarial, and other educational work, fell to a small staff organized by Aida M. Doyle. In 1925, two years after the creation of this section, she transferred from the Bureau of the Census, Department of Commerce into the role "Aid in Organic Chemistry and Foods," which combined projects in organic chemistry, the chemical industries, and the section on foods under a single head. This combination of industries made sense at the time because of the close connection between chemical by-products. "Raw materials of the organic chemical industries consist largely of by-products of the coal, wood, petroleum oil, farm and cattle industries." Doyle thus emphasized that "chemistry therefore is of great importance not only in itself but as an equalizer between agriculture and the mechanical industries."[266] In an institution that focused on the development of the United States, there was a logical place for the chemical technologies which played a prominent role in the nation's industrial sector. However, the extant annual reports written by Doyle chronicle the disciplinary and practical challenges associated with collecting and displaying contemporary chemical artifacts in a public institution.[267]

Chemistry itself, because of its omnipresence was difficult to exhibit. "The subject of Chemistry is large, of deep underlying importance and of great difficulty in

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[265] Annual Report 1923 Smithsonian Institution RU000240, National Museum of History and Technology (US) Division of Agriculture and Mining Records c. 1923 – 1973 Box 10 of 14 Folder: Section of Chemical Technology Annual Report
[266] Ibid.
[267] C.C. Anderson prepared the first report in 1923. A.M. Doyle wrote all following reports in the archival record 1935-43.

presentation. Chemistry appears in many forms in every industrial operation and is entitled to space under each and all of the groups of industries." Doyle imagined chemistry as a topic that should be integrated into all industrial exhibits, rather than only keeping it in a small section that drew upon examples from many fields. She cited this as "the plan being followed by the more recently established museums, and is the only logical method," implying that her institution's current narrative strategy and organizational scheme was out of date. Doyle criticized the prevailing practice of "static exhibits" as especially problematic for the topic of chemistry. "In time, all museums will have dynamic exhibits in the fundamentals of chemistry and methods of manufacture of industrial products, the latter to include the fundamentals of physics and of engineering, just as study courses in the universities of late years include Chemical Engineering."[268] For Doyle, a dynamic exhibit was one that combined both the basic science and its application shown together. "Statically they are undemonstrable *(sic)*. To prepare exhibits in industrial chemistry, new materials, new plans and new appropriations are required…exhibits must be dynamic."[269] Moreover, many examples of more conventional chemical products came in the form of generic looking powders that made them difficult to appreciate unaided. Not surprisingly, Doyle worried that the public would find such a display dull. "Chemistry functions only with changes in internal composition that cannot be demonstrated statically to advantage. Rows of bottles and articles showing raw materials, stages of manufacture and finished products, formerly

[268] Annual Report 1935 Smithsonian Institution RU000240, National Museum of History and Technology (US) Division of Agriculture and Mining Records c. 1923 – 1973 Box 10 of 14 Folder: Section of Chemical Technology Annual Report
[269] Annual Report 1937 Smithsonian Institution RU000240, National Museum of History and Technology (US) Division of Agriculture and Mining Records c. 1923 – 1973 Box 10 of 14 Folder: Section of Chemical Technology Annual Report

thought sufficient, have little appeal to the general public now that dynamic exhibits are common."[270]

Despite the fact that elsewhere at the Smithsonian exhibition work was combined with research, the annual reports demonstrate multiple failed attempts made by Doyle to establish chemical research within the section.[271] A member of the American Chemical Society, she regularly attended professional meetings and sought opportunities to maintain connections to developments in the field. Although she was permitted time away from the department to attend conferences and meet with industrialists, these efforts were through her own initiative and at her own expense. In response to the request for a laboratory she was "assured that as soon as practicable equipment will be provided." Doyle also offered to furnish temporary equipment at her own expense to use in the interim, but was also rejected. Her frustration grew with each year, especially in the standardized report sections on "4: Investigation and Research" and "10: Educational Work."

Doyle recalled that when she was working at the Bureau of Chemistry, she "was considered an expert on identification of coal-tar dyes and related compounds, samples being referred to me in this capacity from all of the government departments and from innumerable outside sources. I should like the privilege of re-establishing such a reputation."[272] Furthermore, she thought it impossible to fully understand industrial science without being permitted to visit "manufacturing conditions on the spot," a request that had been denied despite making a case for this type of research as

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[270] Annual Report 1936 Smithsonian Institution RU000240, National Museum of History and Technology (US) Division of Agriculture and Mining Records c. 1923 – 1973 Box 10 of 14 Folder: Section of Chemical Technology Annual Report
[271] In the 1927 report she cites the laboratory in the geology department as a precedent.
[272] Annual Report 1928 Smithsonian Institution RU000240, National Museum of History and Technology (US) Division of Agriculture and Mining Records c. 1923 – 1973 Box 10 of 14 Folder: Section of Chemical Technology Annual Report

fieldwork, a common and accepted practice in the natural sciences departments such as botany and geology elsewhere at the Smithsonian.

The changes within this section during its first twenty years of operation reflect broader trends in American chemical development, beginning with natural products, moving to synthetic materials intended to mimic nature, and finally emphasizing rubbers and plastics. In addition to chemical products, the section also included models of industrial plants beginning in 1926 with the acquisition of a Borden model farm and condensed milk factory, and on loan from the Ford Motor Company, wood distillation and coal distillation plants. It is important to note that these exhibits were meant to communicate the current state of the art rather than feature chemical technologies in an explicitly historical perspective. "The work of this section particularly deals with materials that have no past from a manufacturing status in this country, nor can the essential facts connected with chemistry be made evident to the eye."[273]

Doyle emphasized the explicit separation between what she saw as the exhibition of contemporary materials and corporate promotion, "As stated before, we do not ask for historic pieces that exploit the deeds of the past and save storage space and costs while at the same time advertising the donors in a great Museum with millions of visitors." She did not want to collect pieces that had already lost their value in the eyes of the originating companies and were just taking up space in their own warehouses, but to rather communicate about the state of the art to the museum's visitors. The contemporary nature of the exhibits and disinterest in corporate promotion also made acquiring artifacts difficult. An exasperated Doyle reported that during the mid-1930s "it has been difficult to bring manufacturers to the point of making appropriations for a

[273] Annual Report 1937 Smithsonian Institution RU000240.

gift exhibit to the museum."[274] She described this period as "characterized by promises and postponements. Industry though 'recovering' is apparently feeling uncertainty as to the outcome of moves made in interest of recovery and is holding extra outlays such as museum exhibits at a very low ebb."[275]

Staff with chemical expertise and belief in the importance of industrial chemistry, combined with physical artifacts from the contemporary world of innovative products and processes could not create chemical education programs that they deemed successful without the support of their home organization and business partners. Although the reports from the Section on Chemical Technology throughout the 1920s and 30s highlight the section's sporadic and sometimes strained relationships with corporate donors around the exhibition of contemporary products and processes, this was not indicative of the reluctance of businesses to engage in chemical education through exhibits at this time. However, they more often focused their efforts on reaching the public through the medium of the World's Fair, periodically repeating, high-budget ephemeral spectacles that blurred the line between education and marketing.

In some respects, a large and diverse national museum, like the Smithsonian, that featured contemporary industrial developments and a World's Fair have much in common. They were both specialized places where visitors could learn through interaction with temporary exhibits that featured physical artifacts. Despite the high visibility of corporations and their brands at the fairs, in order to achieve tax-exempt status the fair as a whole needed to declare an overall educational mission.[276] Although

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[274] Ibid.
[275] Annual Report 1936 Smithsonian Institution RU000240.
[276] Campbell Films' interview with Robert Moses Oct 27 1960, *1964 New York World's Fair Report* Prelinger Archives http://www.archive.org/details/1964NewY1961

many World's Fair exhibits were meant to be instructive, they were nonetheless not bound to the high educational standards of a museum. Both venues endeavored to keep the attention of a visitor and to impart information, but the museum could not so obviously focus on entertainment. In this context, Doyle's concerns about the need for dynamic exhibits to effectively communicate about chemical technology to the U.S. National Museum viewers were also shared by corporate pavilion designers. Although they too were looking to leave behind the older static exhibition style, corporate exhibit designers wanted to achieve a strategic balance between educational and more commercially overt exhibition styles. Historian Roland Marchand describes the end of the 1930s as a critical period in the shift of corporate image exhibition strategy from one closely related to the subdued tone that had been traditionally associated with educational materials to a newer and more theatrical style of spectacle. Historian Pamela Laird characterizes advertising as "the business of progress," in her analysis of visual materials 1870-1920s, *Advertising Progress: American Business and the Rise of Consumer Marketing.*[277] In *Creating the Corporate Soul (1998),* Marchand not only attributes this presentation choice to the way that exhibit designers imagined the interest and attention span of the average consumer, but also to the fact that industrial processes were becoming increasingly difficult to portray in their entirety due to the large scale and intricacy of factory processes.[278]

Despite the seeming similarities between a museum exhibit and a corporate exhibit, one might be hard pressed to truly mistake a World's Fair pavilion for a public museum. Though of course the latter continued to share many attributes with the emerging genre of the corporate museum. Indeed, the corporate pavilions at World's

[277] Pamela Laird, *Advertising Progress: American Business and the Rise of Consumer Marketing* (Johns Hopkins University Press: 1998) 2.
[278] Roland Marchand, *Creating the Corporate Soul (1998)* 290 – 301

Fairs were instructive. Nonetheless, rather than aiming to present chemistry as a central focus for an exhibit as part of a general education scheme, they took a more consumer-oriented strategy of presenting their products. In this context they hoped to increase their value by linking new products to their origin stories in research and development as well as to their role in an envisioned improved quality of life. The history of World's Fair and museum exhibits are, of course, rich topics in their own right.[279] My interest in making this comparison to the World's Fair genre is not meant to dwell on them specifically, but to use them as a tool for thinking about narrative strategy around science and innovation grounded in the presentation of objects.

Industrial science might produce physical objects that people could recognize, and perhaps even purchase in their daily environment. However, there is nothing inherent about the particular bond structure in a repeat unit of nylon, for example, or even the drape of the fabric itself that makes the processes of research and development, or manufacture obvious to a person at first encounter – not even if that person were a scientist. While many of these artifacts, and their associated scientific processes could be mobilized by popularizers of science, institutional leaders, or corporate brands in the service of a particular idea of progress, yet without narrative they are silent things in an increasingly crowded technological landscape. These specific objects and their associated industries could serve as placeholders that change along with the narrative of progress. For example, both nylon and rolled sheet aluminum, as remarkable as these

[279] For more information on the World's Fairs, see: Joseph Corn. *Imagining Tomorrow : History, Technology, and the American Future.* (Cambridge Mass.: MIT Press, 1986); Robert Rydell. *Fair America : World's Fairs in the United States.* (Washington DC: Smithsonian Institution Press, 2000); Pieter Wesemael, *Architecture of instruction and delight : a socio-historical analysis of world exhibitions as a didactic phenomenon (1798-1851-1970)* (Rotterdam: Uitgeverij 101, 2001); Lawrence Samuel, *The end of the innocence : the 1964-1965 New York World's Fair* (Syracuse: Syracuse University Press, 2007)

new materials were in and of themselves, they could just as easily retreat from the spotlight of high-tech products into the prosaic world of the everyday. Just as attention would eventually shift away from plastics, the same may yet happen to solar cells and related products in the near future. All technologies have the potential in their time to symbolize a particular idea of better future; however any position at the leading edge is sure to be transient as new information emerges and new technologies come to take the place of the old.

CONCLUSION

Both the Mellon Institute and MIT allow us to think about infrastructure for innovation through their programs of early-stage academic-industrial cooperation. The leaders at these institutions created systems of coordination between their own research agendas and opportunities to address industrial problems for both practical and lucrative ends. They both created specialized flexible laboratory spaces that were meant to facilitate new discoveries within their walls, while establishing an environment of stability and legitimacy through the visual architecture itself. The leaders at Mellon Institute and MIT also took on roles outside of their immediate organizational positions, participating in international professional networks and influencing government and policy related to science, technology and education.

Although both institutions addressed academic-industrial cooperation through formalized mechanisms designed to attract corporate partners, the place of industrial science was quite different in each context. The Mellon Institute was founded with the purpose of promoting industrial science explicitly as part of its mission. Although basic science was clearly present within the Mellon Institute's research portfolio, (and the focus on this type of work would even increase in the 1950s and 60s before the merger with Carnegie Tech) industrial science was always its primary identity. MIT, on the other hand, worked to maintain industrially relevant research within its activities, but was careful to not let it dominate its overall mission. This strategy was evident in the way that textile research operated in practice at MIT, especially with regard to the relationship with the Lowell Textile Institute. Despite the obvious common interests between the textile lab and the Lowell Institute, the latter was always kept at arms length in important decision-making. Although originally envisioned as a component of MIT, the Lowell Institute had to forge its own independent (and less prestigious) identity.

The place of a formal education program was also a major difference between MIT and the Mellon Institute. MIT was undoubtedly a school for both undergraduate and graduate students that integrated a research component into its major activities. By contrast the Mellon Institute operated in partnership with the University of Pittsburgh, but it did not itself grant degrees. All of the fellows joined the Mellon Institute with at least bachelor's level training already acquired; the majority had graduate degrees. It was, however, possible for fellows to earn graduate degrees through their work at the Mellon Institute if they were affiliated with a program at the closely associated University of Pittsburgh.

Both the Mellon Institute and MIT, created models for industrial engagement that were critical in shaping the technological landscape for chemical industrial innovation in the early decades of the 20th century. Nevertheless, without narrative to bind them into a cohesive productive mechanism, their programs, offices, and fellowship systems would have been little more than a scattered array of organizational structures. Narrative is especially useful when concepts are emerging; it can create bridges between apparent opposites, and join them for productive ends. This is one reason why it is such an important part of the story of industrial science, a field created at the intersection of science and business, growing into prominence at the beginning of the 20th century.

After the Second World War, the narratives of progress as told through consumer products grew even more prominent, especially at the World's Fairs. Fifty years after Duncan published his series of books, he would have easily recognized his idea of the "era of gracious living," in Walt Disney's post-war conception of progress. The new American society with its increased leisure time and homes filled with products derived from the work of industrial chemists, manifested itself in display, a shiny caricature of a consumer-oriented future told at the World Fairs. These products, fantastical as they seemed on display, also often reflected those available in retail stores. For example, at the 1964 World's Fair in New York, Walt Disney crafted his own narrative of a better future for the average American into what he called "Progressland." This place featured the importance of electricity in order to showcase General Electric. Disney's spectacle of progress as articulated through this exhibit was a physical artifact of narrative in the making. His moving theatre display, the so-called "Carousel of Progress," was explicitly framed in terms that Duncan would have appreciated. As visitors began their journey, an animatronic American father greeted them with the following words:

> *Welcome! To the General Electric Carousel of Progress.*
> *Now most carousels just go 'round and around without getting anywhere.*
> *But on this one, at every turn, we'll be making progress.*
> *And progress is not just moving ahead.*
> *It's dreaming and working and building a better way of life.* [280]

Indeed this exhibit was a bit different both in structure and character from an ordinary carousel with painted horses bobbing as they spin to delight their riders who watch the outside world go by. This carousel was rather a revolving theatre that both

[280] Introduction to Carousel of Progress at the 1964 World's Fair in New York
http://www.carouselofprogress.com accessed October 27, 2009
http://www.yesterland.com/progress.html accessed May, 9 2014

interpreted the past and envisioned a not-too-distant future for its visitors, who remained seated and directed their attention inward to an unfolding story of the "progression of modern life" as told through sequential advances in household technology by animatronic 'actors.' Rather than spinning back to a fixed place, this carousel carried its passengers in a corkscrew-shaped journey. In this case it was not the outside world that passed by the perimeter of the carousel, but instead the viewer who circled around an animatronic story continuously playing at the center of the structure. It spiraled around ideas of polity, economy and society, refining them with every turn into a linear modern day myth of "the American way-of-life" as facilitated by advances in technology, notably GE's specialty, electricity. This explicit and physical narrative of progress would find a new home after the end of the fair as the "New Tomorrowland" section of Disneyland in 1967. Remarkably, not unlike Maclaurin with his Tech Plan, and Duncan with the Mellon Institute, Disney would also die shortly before the realization of his vision. Although this is nothing more than coincidence, the untimely deaths of these individuals in the midst of the realization of their forward-looking plans serve to highlight the inherent fragility of any scheme to engineer an ideal future. All of these plans, despite losing their creators found their way to completion. Ironically, the power of their narratives grew even stronger as the recently departed leader could be appropriated as a figure within their own narrative of progress now retold by others. They could, in effect, become an abstracted legend from which to draw new strength.

As historians, we study change over time. The questions that we ask of the past are also part of this process of change, embedded in our own present. This dissertation project, which in many ways tells an origin story for a particular type of academic-industrial cooperation, reflects the economic, political and technological circumstances of early 20th century America. However, many of the questions that motivated my historical actors clearly resonate in our contemporary world. In 1907, Duncan asked, "How do we utilize modern knowledge?" In 1920, Maclaurin envisioned the role of research universities as consulting bodies. In the face of the Second World War in Europe, Compton saw the development of science as a bloodless alternative tool of empire, poised in opposition to the Nazis and Fascists, yet powerfully apolitical. In our contemporary world science and technology are still sought as solutions to societal challenges, both social and environmental.

While perhaps the particular language style and the nouns (especially the proper ones) may change, the verbs, and the sentiments that they carry remain resonant a century later. Charismatic leaders can be replaced by yet other charismatic leaders; in effect, they transition from physical beings into ideas. Perhaps their narratives are retold, appropriated into the work of their successors. The industries too, though they might remain in operation over longer periods than a single human lifetime, enjoy only a fraction of that lifespan at the so-called cutting edge. The laundry industry, for example, which certainly held significance for Duncan and Speare and precipitated the launch of the industrial fellowship system at the University of Kansas, doesn't carry the same aura of relevance in the contemporary technological landscape captivated as we are now by biotech and alternative energy developments. This doesn't mean that there are no longer unmet chemical challenges associated with laundering and textile processing. In fact such challenges are abundant, especially with regard to environmental impact. Nonetheless, laundry no longer captures the popular imagination. The material outcomes themselves, whether they are new types of rubber, stronger plastics, or longer-lasting loaves of bread, blend together into a category of things cast into a cycle of treasure and discard.

Through an explicit focus on narrative in historical context, we gain perspective on systems of production that blend the abstract world of ideas with the tangible realm of things. The verbs — such as create, coordinate, build or even imagine — which continue to carry significance are brought into contrast with the nouns such as chemical or textile industries that somehow seem outmoded to a contemporary ear. It is precisely this apparent discord that is important for the historian to interrogate. Here at this intersection the constant and variable meet, a variation on the mangle of practice, where the action of verbs remains the same and their associated nouns interchange in a dance of agency.

Narratives are the stories that we tell to make sense of a messy world, fraught with contradictions. Thus, one might ask – what are our contemporary narratives of progress in the making? Does the language of crisis management associated with environmental impact and climate change outweigh the impetus to build new structures in the image of an ever-shifting idealized future? Does digital learning offer a new space to bridge technical and technological education on a global scale? The answers to these questions, and others like them, require an approach that takes into consideration coordinated systems of people, things, and ideas - not only their mechanisms of action but also the stories that emerge around and about them. This is the focus of scholarship like mine, to engage with the institutional and narrative underpinnings of innovation, an iterative process of change through which coordinated systems of people can envision their future.

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