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"NOTHING LESS THAN A REVOLUTION": HENRY PRENTISS ARMSBY AND THE ROLE OF SCIENTISTS IN SOCIETY, 1862-1921

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ABSTRACT

Though research oriented public universities are now the staple of higher education in the United States, this was certainly not always the case. The origins of such universities can most directly be found in the mid-19th century amidst the land-grant university movement. The leaders within this movement called for the federal government to provide funds to states for the establishment of universities tasked with providing more scientific education to students of all social classes. Over time, these universities received funding to establish agricultural experiment stations where fundamental scientific research could be performed. That development may have been in the direction of modern research universities, but the scientists working in those early land-grant institutions were different from modern scientists in remarkable ways. This thesis seeks to analyze those differences by focusing on the research and writings of one such agricultural scientist, Henry Prentiss Armsby, who worked at the Pennsylvania State College from 1887 to 1921. Armsby's writings reveal him to be a "philosopher-scientist" whose broad academic interests and long-term vision allowed him to play many interesting roles required by the social and political environment in which he lived. This thesis describes the nature of scientific research at the turn of the 20th century and the roles that scientists and their research played within that society through an analysis of Armsby's writings and a comparison to other "philosopher-scientists" of the time.

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INTRODUCTION

"He has left a monument such as few men can boast and his work will live on and continue to fruit in the lives of those who succeed him." These words were written as a tribute to Henry Prentiss Armsby, the man who served as director of the Pennsylvania State College Agricultural Experiment Station from 1887 until his death in 1921.[1] Henry Armsby's work as a researcher in animal nutrition was at the forefront of agricultural research during his lifetime and even after his death, his legacy in the field of animal nutrition would far outlive him. Despite that importance, however, not much scholarship has been done on the work and life of Armsby; and seemingly no individual treatments of Armsby have been written in recent years. I believe Armsby's research and writings offer a helpful glimpse into the world of the land-grant movement and the institutionalization of science at the turn of the 20th century. It is therefore the goal of this thesis to bring Armsby into the prominent light I believe he deserves.

Work on this project began during an internship with the Pasto Agricultural Museum at The Pennsylvania State University. The museum curator wished to utilize the Armsby Respiration Calorimeter Building – construction of which lasted from 1898 to 1902, and which is still in a remarkably well-preserved state – as a space to educate visitors about the history of agricultural research at Penn State. In order to gain a fuller picture of the history of the building, the respiration calorimeter itself, and its associated research, she tasked me with reading through a collection of archived materials related to the building. This primarily involved the reading of the Collected Papers of the Institute of Animal Nutrition, which was founded in 1907. It was in the reading of these papers, collected in the Eberly Family Special Collections Library at Penn

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[1] Robert L. Cowan, "Henry Prentiss Armsby, 1853-1921: A Brief Biography," *The Journal of Animal Science* 66 (1988): 1837, *JSTOR*, Online (accessed on 29 November 2017). Dr. E. W. Allen penned these words as a tribute soon after Armsby's death, and Cowan used this quote as the opening line of his short biography of Armsby.

State, that I first "met" the character of Henry Prentiss Armsby.[2] A vast number of these papers were published research articles from Armsby, his staff, and the many associated researchers who worked with the instrument in its nearly 60 years of operation. Though the overall story of research with the instrument was my primary focus for that project, Henry Armsby consistently stood out to me as a unique and interesting figure when compared to the other researchers I was encountering.

Coming into the research, I expected to be reading the focused, highly technical, and often dry scientific research articles I had become familiar with in my science courses here at Penn State. Though this was often the case, Armsby's writings nearly always included sections with a different style. Rather than focusing simply on the data of the experiment itself, Armsby appeared to have little hesitation to discuss the broad and far-reaching implications and importance of his research, a practice often discouraged in modern scientific writing. I soon came to realize that it was not the fact that Armsby thought about these issues which was surprising, but rather his insistence on including those thoughts in his scientific papers. I wondered whether this tendency was unique to Armsby or whether it was characteristic of most scientists living in Armsby's time period. To answer these questions, I began studying the history of the land-grant university movement with which Armsby was closely associated and also began reading the works of other late 19th and early 20th century scientists. The findings of this research form the core of this thesis.

I organized my thesis in such a way as to highlight these major steps in the project. The first chapter, based primarily on secondary sources, will provide a broad survey of the land-grant university movement of the mid- to late 19th century. The socioeconomic and political factors

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[2] Collected Papers of the Institute of Animal Nutrition, Eberly Family Special Collections Library, The Pennsylvania State University, University Park, PA.

associated with this movement were highly influential in the work of scientists at the time, so an understanding of that movement is critical in any discussion of Armsby and his research. The second chapter will analyze three scientists who were contemporary with Armsby and who have received attention in modern scholarship; namely Wilbur O. Atwater, Ellen Swallow Richards, and Eugene Davenport. Utilizing a mix of secondary sources related to these scientists and the primary sources of these scientists' writings, it will be shown how these scientists, and many others of the time, could be classified as "philosopher-scientists," a term I coined in an effort to describe the key characteristics of these scientists. I define it as a scientist who performed advanced and technical research and also promoted the social, economic, or political implications of that research. Further, philosopher-scientists are primarily characterized by their appreciation for broad academic disciplines, including those outside the realm of science. Therefore, they also had broad visions of the impact of their work on the world and frequently spoke of that vision within their writings.[3] The responsibilities of philosopher-scientists within their societal context also led them to play many roles within their society, and a number of their key roles will also be outlined in this chapter.

The third chapter begins the main discussion of Henry Armsby by analyzing his writings; this will help determine how he was also a philosopher-scientist and the ways in which he embodied the many roles tied up in that classification. Also, in a comparison of Armsby and his three contemporaries from the earlier chapter, some key differences and similarities will be highlighted. Finally, the fourth chapter will discuss the scientific work of Armsby to demonstrate his dedication to performing fundamental research in the field of animal nutrition through the use

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[3] This characterization of "philosopher-scientist" arose as a result of a conversation with Dr. Bryan McDonald, an historian at Penn State. After I mentioned to him the things I had observed in Armsby's writings, he explained how that was likely characteristic of many scientists at the time. He argued that many factors likely created that unique style of scientist, as will be discussed in Chapter 2.

of the respiration calorimeter. Armsby was a scientist first and foremost, so this work is critical for understanding Armsby's career.

Overall, this thesis will show that Armsby fits into the phenomenon of philosopher-scientists at the turn of the 20th century; not only did he perform advanced and technical research, but he also consistently made an active effort to demonstrate the importance of that work and to advocate for the promotion of such fundamental research. I hope this will not only bring Armsby into the light of modern scholarship, but I believe this discussion also provides an archetypal example of the kind of scientists associated with the highly important land-grant university movement of the 19th century.

CHAPTER 1

A History of the Land-Grant Movement

The leading role of research-oriented universities may be the defining characteristic of modern scientific research in the United States, but for much of the nation's history, this was not the case. In fact, most Americans of the late 18th and early 19th century would likely never have expected their nation to develop an educational system so closely tied to scientific research funded by the state and federal governments. Many of the early private universities – including Harvard University, founded as the first American university in 1636 – focused primarily on the teaching of classical subjects and languages, and were often characterized by heavy religious influence. However, by the beginning of the 20th century, the patterns of American higher education had shifted. These newer universities, though still having some characteristics of those earlier American universities, were often publicly funded, and they also now placed much higher emphasis on the teaching of science and the promotion of scientific research. This change can be attributed to a number of economic and societal factors, but regardless of how those factors interacted, it was ultimately the passage of specific Congressional legislative acts aimed at creating "land-grant universities" which provided the final push toward creating this new educational environment. Though this shift seems abrupt, and perhaps in certain ways it was, there were multiple factors which ultimately culminated in this change. Henry Prentiss Armsby worked in the midst of this radical shift, so an understanding of the factors which contributed to the "land-grant movement" will serve to better contextualize his work. This chapter seeks to tell the story of that movement in an effort to highlight the influences on Armsby's work and will provide an historical backdrop against which Armsby can be portrayed.

The land-grant movement most directly traces its origins to the mid-19th century. On the whole, this century saw many changes to various facets of American life. As the world became increasingly industrialized, many Americans feared that the United States could fall behind its European counterparts if the nation did not find a way to educate its citizens in the newly forming principles associated with that industrialization. In addition, many Americans were also worried about the impact of rising urbanization. Granted, the American population was still largely agrarian, but as greater numbers of people moved away from farms to settle in the growing urban centers, Americans feared the potential loss in agricultural productivity this urbanization could cause. In these ways, increased urbanization created a variety of opportunities and challenges for American society, and amidst these changes, the land-grant movement was born, struggled for influence as it developed, and ultimately received the support it needed to progress successfully into the 20th century.

As mentioned above, American higher education earlier in the nation's history differed markedly from what would later arise. Following the American Revolutionary War and into the early 19th century, the new nation's education system sought to instill the republican values many believed were necessary for the success of the young republic.[4] Leaders and educators hoped that by proliferating ideals regarding active and dutiful citizenship among Americans, the young nation could be successful. Therefore, it was only natural for the desire for universal education to arise in order to proliferate those ideals most efficiently. As Roger Williams, an historian of higher education, explains, widespread education was viewed as being necessary for the "vitality of a self-governing people."[5] By the 1820's, as the electorate expanded across the nation, calls

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[4] Roger L. Williams, *The Origins of Federal Support for Higher Education: George W. Atherton and the Land-Grant College Movement* (University Park: The Pennsylvania State University Press, 1991), 13.
[5] Ibid., 14.

for a universal education system also grew, becoming, as Williams describes it, "a staple of American politics."[6] Because of this parallel growth of the American electorate and the calls for a universal American educational system, from its earliest iterations American higher education can be viewed as an institution through which the American public could prepare the nation for the future which lay ahead of it.

As the land-grant movement gained momentum during the mid-19th century, a similar desire to prepare the nation via its educational system led the charge. However, the perceived needs of the nation had begun to change by this point, so Americans began to desire a new style of American higher education which addressed those new needs. Ultimately, the land-grant movement developed to address these new desires.

In his book on the history of the land-grant movement, Williams lists a number of factors which he believes combined to create the atmosphere needed for the beginnings of this movement. This list includes the aforementioned expanding electorate as well as "an emboldened agrarianism" and the emergence of an industrial economy.[7] These latter two factors, as explained above, were in many ways one and the same. The rise of industrialization around the world not only began to fundamentally change the economies of newly industrialized nations, but it also appeared to threaten the foundations of the traditional agricultural economies that had long existed in these nations. The proposals for dealing with these changes, as well as the land-grant movement which emerged amidst these concerns, were therefore influenced by various groups within society. Some of these groups desired American education to focus on teaching methods for refining the new industrial economy and practices associated with that endeavor. Others desired an American educational system focused on agricultural pursuits to bolster the

[6] Williams, *Federal Support,* 14.
[7] Ibid., 11.

traditional agrarian economy against industrialization. Many sought to find a way to incorporate aspects of both pursuits. These diverse concerns would play a critical role in the development of the land-grant movement.

The practice of advancing specifically for the cause of agriculture had a long tradition in American society. The first organization to be formed for the cause of agricultural reform in America was founded in 1785, very early in the nation's history. This organization was The Philadelphia Society for Promoting Agriculture.[8] The Philadelphia Society focused on issues regarding various methods of increasing crop yield in Pennsylvania, but as Michael Bezilla explains in his book on the history of agriculture at Penn State University, "[T]he Philadelphia Society…had little concern or identification with ordinary 'dirt farmers.'"[9] Rather, this society, and the others like it that would later arise, consisted mostly of gentlemen farmers whose primary occupations were non-farming related pursuits such as law, medicine, or banking.[10] A desire to educate the "dirt-farmers" of America had not yet formed, and though some farmers began to worry about the depleted nutrients of soil in the heavily farmed areas of the original American states, a nation-wide concern for broadly promoting American agricultural reform had not yet reached the levels necessary for creating a national movement for agricultural education.

When the land which would later form the states of the Midwest and Mississippi River Valley was opened for settlement in the early 1800s, whatever concern for soil fertility and agricultural reform had arisen in the East was halted as settlers found cheap land and fertile soil

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[8] Michael Bezilla, *The College of Agriculture at Penn State: A Tradition of Excellence* (University Park and London: The Pennsylvania State University Press, 1987), 2. This source served as an excellent narrative of the history of Penn State, specifically regarding the study of agriculture, so it formed the basis of the narrative for this chapter as well. I used the other sources in this chapter to help frame the narrative in its historical context and highlight some of the key themes which are critical to my analysis.
[9] Ibid., 2.
[10] Interesting examples of specific figures contained within this broader class of gentleman farmers interested in agricultural experimentation are George Washington and Thomas Jefferson, as discussed in ibid., 2.

in these new areas.[11] By the 1840s however, some eastern farmers again returned their attention to improving agricultural practice in their area. A prime example of why this occurred can be seen in the case of Pennsylvania. The state had a long tradition of commercial agriculture, and had for most of the nation's history been, in a sense, the breadbasket of America due to its high production of wheat and close proximity to major cities. However, once farms in the midwestern states had come into their own, the enormous output of grain from these areas and the new technology involved in harvesting and transporting that product overcame that of Pennsylvania. In fact, between 1840 and 1860, Pennsylvania wheat production fell from the second ranked state to the sixth.[12] Desire to better compete in this market as well as a desire for the state to begin focusing on other agricultural products led to a renewal in the state's initiative to create a school dedicated to promoting agriculture.

A prominent figure in this renewed interest in agricultural reform was a man named Frederick O. Watts, from Carlisle, Pennsylvania. In early 1851, the Philadelphia Society for the Promotion of Agriculture pushed for the creation of the Pennsylvania State Agricultural Society in an effort to address the concerns of Pennsylvania farmers across the state.[13] Watts was soon elected president of this society. Watts was certainly a part of the aforementioned class of gentleman-farmers, his primary occupation being an attorney, but he had long been passionate about agriculture, doing agricultural experiments of his own on his Carlisle farm.[14] This passion and experience with experimentation led Watts to advocate for the creation of an agricultural school where such methods could be taught to the farmers of Pennsylvania.[15] Watts and The

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[11] Bezilla, *College of Agriculture*, 4.
[12] Ibid., 8.
[13] Michael Bezilla, *Penn State: An Illustrated History* (University Park and London: The Pennsylvania State University Press, 1991), 3. Like Bezilla's other work, this source also served as an excellent narrative for the history of Penn State.
[14] Ibid., 4.
[15] Ibid., 4.

Pennsylvania State Agricultural Society, desiring to create such an agricultural college, received a charter for the creation of The Farmers' High School in 1854, but a number of challenges inhibited establishment.[16] However, on February 22, 1855, Governor James Pollock issued a new charter which corrected those inhibiting factors, officially allowing for the founding of The Farmers' High School, a four-year college offering education in agricultural pursuits. Based on an educational model used in Europe for over a decade, this new school would promote the study of agriculture at the collegiate level.

Pennsylvania was not alone in this renewed desire for agricultural education. However, in 1850, there were no colleges in America offering this kind of education.[17] Across the world, though, this type of education was not entirely novel. In 1850, Amherst College president, Edward Hitchcock, conducted a survey of over 350 European universities and research stations associated with the scientific study of agriculture. His findings were a popular read among agriculturalists in America, and deeply impacted those wishing for American agricultural colleges.[18] Many successful agriculturalists, including Justus Liebig of Germany and Sir Joseph Gilbert of England, had received worldwide acclaim from their work with these European institutions.[19] The fact remained, however, that such institutions did not exist in America, and the few agricultural scientists living in America at this time had received their education at these European institutions. Pennsylvania led the charge to change this fact. But what aspects of those European universities and research stations would American innovators wish to emulate? Bezilla explains the findings of Hitchcock's survey of these institutions as follows.

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[16] These inhibitions included an unwieldy number of trustees, among others, as described in Bezilla, *College of Agriculture*, 12 and Williams, *Federal Support*, 33.
[17] Bezilla, *College of Agriculture*, 9.
[18] Ibid., 9.
[19] Ibid., 8.

> [Hitchcock] asserted that the most successful facilities were those controlled by or receiving aid from the government. Hitchcock also maintained that the most valuable work was being done at the college level, where research could be blended with theoretical and practical instruction in agriculture.[20]

These two characteristics, namely government funding of research and a blend of theoretical and practical education, would form the core tenets of the American land-grant legislation.

The Farmers' High School attempted to mirror these characteristics as well. After deciding upon a 200-acre plot of land in Centre County, twelve miles south of Bellefonte, the Board of Trustees of this young institution began seeking funding. Though much of this initial funding did come from private donations, in 1857, the Pennsylvania General Assembly granted $25,000 to the school, even promising to repeat this grant if the school continued to raise private funds as well.[21] This was a marked divergence from the traditionally private universities which had long been the staple of American higher education. However, it was also a move in the direction of the successful and government-funded European universities of Hitchcock's survey.

This adherence to the educational traditions of Europe was also demonstrated in the Board of Trustees' choice for the first president of their school when, in February 1859, Evan Pugh was named president of The Farmers' High School.[22] Though Pugh was born in Chester County, Pennsylvania, he had decided to abandon his father's trade of blacksmithing, instead choosing to study agricultural chemistry in Europe. He received his Ph.D. from the University of Göttingen in Germany, and also worked for a time at the renowned Rothamstead experiment station in England.[23] These experiences made him the ideal candidate for filling the role of president at The Farmers' High School, and knowing what would later become of that university

[20] Bezilla, *College of Agriculture,* 9.
[21] Ibid., 12.
[22] Bezilla, *Illustrated History,* 8.
[23] Ibid., 8.

only further shows the wisdom of choosing Pugh for this critical position at this formative time. Having seen firsthand the organization of educational and research institutions in Europe, Pugh was prepared to craft The Farmers' High School into a similar institution. His first focus was to garner more financial support for the school, and after an initial failed attempt at passing state legislation to achieve this, a later bill, for which Pugh had helped garner support from local agricultural societies, granted $50,000 from the state government to the school in 1861.[24]

Pugh also began to see a new role that the college could play in preparing Pennsylvanians for the changing economy of the time. Specifically, Pugh began to push for the school to provide education in the "mechanic arts," what we now know as engineering.[25] Eyeing the growth of industrialized pursuits such as mining and manufacturing in the Pennsylvania economy, Pugh believed if Pennsylvanians were trained in these areas, as well as in agriculture, the state would be equipped to handle any changes which may arise from the new industrialization. However, he also bucked the trend of the other agricultural colleges at the time. The few other institutions which had begun to form in recent years had often focused heavily, or exclusively, on vocational training. Pugh did not want this to be the nature of education at The Farmers' High School. Rather, as Bezilla explains in his book on the general history of Penn State, "[Pugh] conceived of a college that could combine the best elements of classical education with those of utilitarian training."[26] As discussed earlier, classical education had long focused on instilling ideals which could better prepare Americans for their civic duties. For Pugh, this likely extended to their understanding of broad scientific topics to better inform their work with more specific practical pursuits. Therefore, put another way, Pugh desired to create in Pennsylvania a school which

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[24] Bezilla, *Illustrated History,* 9.
[25] Ibid., 10.
[26] Ibid., 10.

bettered its students lives in regards to both their theoretical understanding of broad topics as well as their ability to perform practical tasks necessary for the changing Pennsylvania economy.

By the 1860s Pugh was not the only educational leader who desired to create this new style of education in America. These men, and their industrial and agricultural concerns, were mirrored by Justin Smith Morrill, a Congressman from Vermont, whose namesake legislation would form the foundations of the land-grant movement. Morrill's dedication to advancing these agricultural and industrial concerns can be seen in his motivations behind his legislation. Years after this legislation was passed, Morrill outlined his motivations, explaining that

> most of the existing collegiate institutions…were based upon the classic plan of teaching those only destined to pursue the so-called learned professions, leaving farmers and mechanics and all those who must win their bread by labor, to the haphazard of being self-taught or not scientifically taught at all.[27]

The influence of scientific teaching will be addressed later, but for the present discussion, the importance of this quote lies in Morrill's sympathies for the farmers, mechanics and others who "win their bread by labor." As mentioned above, many early examples of men advocating for agricultural reform were gentleman-farmers with little to no concern for the needs of the "dirt-farmers." However, Morrill clearly believed the existing system of higher education at the time was not successfully catering to the needs of the working classes, and his specification of farmers and mechanics showed his desire to appeal to those classes directly affected by industrialization. This sentiment marks another characteristic of the land-grant movement, namely that its proponents believed their primary concern ought to be for the working class and not just for the elites of American society.

Morrill sought to ensure that this concern be enshrined in a new system of higher education through his legislative work. The Morrill Act of 1862 created that system through the

[27] Williams, *Federal Support*, 20.

granting of federal land to states which were then to be used for funding colleges. Though this specific system was unique at the time, this legislation did not emerge from a vacuum. As Williams describes, the 1862 Morrill Act was largely a catalyst in a process which had begun decades prior. The Land Ordinance of 1785 contained the first example of land grants being used to support public education. The schools created under this system, however, were primarily "common schools" focusing on grade school education. The first major example of land grants being used to create publicly funded institutions of higher education can be found in the Northwest Territory Ordinance of 1787, under which two townships near the center of the states in that region would be used to support a "literary institution" for that state. An 1836 change to that system then allowed for the founding of two separate institutions of higher learning in those states, a "seminary of learning" and a "first state university."[28] However, a new trend then emerged in 1862 when President Abraham Lincoln signed a piece of legislation proposed by Morrill. An earlier draft of that bill, proposed in 1857, had been vetoed by President James Buchanan, but the passage of the later bill, now known as the 1862 Morrill Land-Grant Act, set the stage for a new form of higher education to arise in the United States.

Even with the aforementioned early precedents of federally authorized land grants used for the founding of colleges and universities, the land-grant colleges created by the 1862 Morrill Act were unique in their purpose and character. This uniqueness lays in their focus on the teaching of agriculture and the mechanical arts. As was seen in Morrill's quote above, the education of farmers and the industrial working class was central to the legislation's design. And this focus was permanently mandated in the text of the 1862 Morrill Act itself. Therefore, in

[28] Williams, *Federal Support*, 35.

order to understand the intended focus of the land-grant colleges, as well as their means for being created, an analysis of the text of the Act is required.

The opening paragraph of the Act explains how the funding for the land-grant colleges would be acquired. It reads,

> Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, that there be granted to the several states, for the purposes hereinafter mentioned, an amount of public land, to be apportioned to each state a quantity equal to thirty thousand acres for each senator and representative in Congress.[29]

As in the Act itself, the "purposes hereinafter mentioned" will be discussed below, but regarding funding, this passage describes the basics of the source of funds for these new colleges – namely, the federal government would grant land to each state. The state would then sell that land, and the funds acquired by the states from those sales would be used to establish and fund the institutions which would later, appropriately, be called land-grant colleges. As described above, the granting of land by the federal government for funding higher education was not an entirely new practice, but the 1862 Morrill Act was noticeably different in a few ways. For example, the amount of land granted to each state would be proportional to that state's representation in Congress. Because of that, states with larger population would therefore receive more land, and consequently more funding for their land-grant colleges.[30]

Regarding the usage of the funds received from these land grants, the states were required to utilize those funds for "the endowment, support, and maintenance of at least one college where the leading object shall be, without excluding other scientific and classical studies,

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[29] "Transcript of Morrill Act (1862)," Our Documents, accessed March 25, 2019, https://www.ourdocuments.gov/doc.php?flash=false&doc=33&page=transcript.

[30] This issue was one of the central points of contention during debates over the Morrill Act of 1862, as well as a failed precursor to the act, another Morrill Bill of 1857. During the debates over each of these bills, states in the West favored a more egalitarian distribution of land-grants to the various states. This contention, as well as concerns over constitutionality and viability of enforcement methods ultimately led President James Buchanan to veto the 1857 bill, and these issues also presented themselves in 1862. These political struggles are well described in Williams, *Federal Support,* 38.

including military tactics, to teach such branches of learning as are related to agriculture and the mechanic arts."[31] These goals fall closely in line with the aforementioned motivations Morrill later attributed to his proposal of this bill, namely that scientific studies and a focus on agriculture and mechanic arts would be primary focuses of these new institutions.

However, it is also worth noting that these motivations closely align with Evan Pugh's desire for education at The Farmers' High School. It is therefore not surprising that Pugh was one among the group of agricultural and educational reformers who advocated publicly for the passage of the legislation. Pugh even traveled to Washington, D.C. to deliver a speech supporting the bill.[32] Because Pennsylvania was a large, populous state, it stood to receive funds commensurate with a large land grant under the 1862 Morrill Act, and this along with Pugh's desire for the success and mission of The Farmers' High School led him to push vehemently for the school receiving the land-grant funding upon passage of the bill.

That desire to receive land-grant funding is first observed at the institutional level when Pugh convinced the court of Centre County to approve a name change of The Farmers' High School to the Agricultural College of Pennsylvania.[33] Pugh believed that the name change would better emphasize the nature of the education taking place at the college, and therefore believed it would better position the school to make a claim on the land-grant funding.[34] These efforts paid off when, on April 1, 1863, Governor Andrew Curtin named the Agricultural College of Pennsylvania the sole recipient of Pennsylvania's land-grant funds.[35] This marked an end to a year long struggle amongst the Agricultural College and other Pennsylvania universities who

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31 "Transcript of Morrill Act (1862)," Our Documents, accessed March 25, 2019, https://www.ourdocuments.gov/doc.php?flash=false&doc=33&page=transcript.
32 Bezilla, *College of Agriculture*, 16.
33 Ibid., 18.
34 Williams, *Federal Support*, 42.
35 Ibid., 42.

also wished to receive all or part of that funding.[36] The Agricultural College of Pennsylvania, and the other universities across the nation who began receiving land-grant funding in the following years, were now in a position to begin fulfilling the mission set forward in the 1862 Morrill Act. However, the land-grant movement was far from finished. Many debates over the precise means of achieving that mission were to soon arise, so this early success was only the beginning of a decades long struggle for legitimacy and stability.

While the factors of industrialism and agrarianism describe many of the earlier debates over the nature of these new-land grant institutions, another two items from Williams' list describe the debates that would overtake the movement later in its development. These items are a "utilitarian impulse" and the rise of agricultural science.[37] The 1862 Morrill Act had established that agriculture and mechanical arts must be taught at the new land-grant colleges, but did not specify the precise means of achieving this. Because of that, the next 25 years would see debates among educational leaders concerning the modes of education at these institutions. These debates would ultimately be settled by another piece of federal legislation, the Hatch Act of 1887.

The "utilitarian impulse," as described by Williams, consisted mostly of a desire to create a practical education for the students at land-grant colleges. This practice had long been performed at various agricultural schools, even before the passage of the 1862 Morrill Act. However, agricultural science, and its effects on agricultural education, had been developing for many years as well. As mentioned previously, the origins of agricultural science trace back to Europe, and any Americans who wished to pursue study in that field would travel to Europe to

[36] The other schools vying for funding and the reasoning for the funds going solely to the Agricultural College of Pennsylvania are explained in greater detail in Williams, *Federal Support,* 42 as well as Bezilla, *College of Agriculture,* 18.
[37] Williams, *Federal Support,* 11.

do so. No such formal education in agricultural science existed in the United States until the 1862 Morrill Act provided a means for that education, but there were many individual farmers throughout American history who were interested in experimenting with different methods of improving their practice.[38] A majority of those individuals, however, were members of the class of gentlemen-farmers, so very little effort had been made to educate the so-called "dirt farmers" in the science of agricultural practice. As seen above, Morrill hoped to create institutions focused on scientific education with his legislation, and upon passage of the 1862 Morrill Act, institutions received the impetus to begin implementing agricultural science in agricultural education, but conflicts between agricultural scientists and farmers – and those political interests purporting to represent farmers' interests – highlighted the various ways in which this scientific education was implemented.

In a 1986 article discussing this conflict between agricultural scientists and farmers, Alan Marcus explains how these tensions often centered around how these scientific principles were employed in education.[39] The agricultural scientists that would come to staff the young land-grant colleges faced the challenge of deciding what sort of curriculum to teach at these institutions. Marcus outlines two specific schools of thought which further develop the ideas mentioned in Williams' list of influences. One group of agricultural scientists believed that the agricultural schools should focus on creating "practical farmers," while another group believed that the schools should be training the "next generation of scientific investigators."[40] The desires of the farmers themselves also influenced the debates over setting up these curricula, adding an extra element of conflict which the leaders of the land-grant movement needed to overcome.

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[38] Williams, *Federal Support*, 28.
[39] Alan I. Marcus, "The Ivory Silo: Farmer-Agricultural College Tensions in the 1870's and 1880's," *Agricultural History* 60, no. 2 (1986): 25, *JSTOR*, Online (accessed on 7 November 2018).
[40] Ibid., 30-31.

Each of these viewpoints are, in their own ways, direct results of the factors of utilitarian education and agricultural science as described by Williams, and because these debates shaped the first couple decades of the land-grant education system, these various schools of thought will be further analyzed below.

In the case of farmers, the majority opinion was that these new agricultural colleges should help the farmers implement more modern organizational principles into the running of their farms. As Marcus explains, the traditional – i.e., non-modern – principles of farming required use of "farmers' backs, muscles, and hands but ignored their brains."[41] Therefore, as farmers saw the success of industrial factories and production, they began desiring to implement the principles of those industries into their farming. They believed that establishing a more systemized hierarchy based on "a collection of rules and principles" would lead to more productive and consequently more lucrative farms.[42] They did not wish to ignore the more traditional values of hard work, however. They just hoped to find new ways of implementing that work. In fact, one major difference between the desires of farmers and agricultural scientists was that farmers supported the manual labor requirements of many agricultural colleges, something nearly all agricultural scientists believed to be unnecessary. Essentially, as Marcus explains, the farmers wanted agricultural colleges to provide an education which taught them to use their minds to direct the work of their hands, seeing this as the best method of bringing farmers into the modern, industrial world.[43]

Regarding agricultural scientists, though there were two schools of thought within this group, a certain common thread did separate their positions from that of the farmers.

[41] Marcus, "The Ivory Silo," 25.
[42] Ibid., 26.
[43] Ibid., 27.

Specifically, agricultural scientists, as may be expected, believed that the most important modern principle to be employed in agriculture was the application of science to agricultural practice. They believed that agricultural processes could be best explained in terms of scientific principles, so farmers ought to be educated in those principles. [44] However, they also, perhaps rightly, believed that a certain level of scientific expertise was needed by those who would be teaching farmers the scientific principles needed in agriculture. This is the impetus for their wishing to focus agricultural education more on scientific endeavors, rather than organizational and business principles. It also explains why agricultural scientists held such disdain toward manual labor requirements – namely, they saw those requirements as being obstacles to scientific education, either because the requirements "weaken[ed] the constitutions of young scholars" or simply took up time that the students could otherwise use for studying.[45] Scientific education was primary for the agricultural scientists, and any other emphasis simply detracted from that pursuit. The point of view of agricultural scientists is perhaps best summed up by Marcus when he explains the process agricultural scientists envisioned, noting that in their ideal system, "Scientists preached, and farmers applied what scientists preached, a situation that demanded that agriculturalists know what scientists were preaching."[46]

Even among agricultural scientists, however, there was a divided opinion regarding the exact nature of the scientific education. Some agricultural scientists desired the graduates of the agricultural colleges to be "practical farmers." Marcus defines these practical farmers as "favoring science, receptive to scientists' teachings, and capable of applying scientific principles learned at college to farming."[47] In order to achieve that goal, the advocates for practical farmers

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[44] Marcus, "The Ivory Silo," 28.
[45] Ibid., 30.
[46] Ibid., 29.
[47] Ibid., 29.

rejected a majority of the subjects taught at classical colleges and instead heavily emphasized the teaching of various fields of science, even if they did not directly relate to agriculture, as these agricultural scientists believed this education in the wider realms of science would better instill an appreciation for scientific principles.[48] The other group of agricultural scientists believed that agricultural colleges ought to focus on training new agricultural scientists.[49] This program of education was characterized by the insistence that students learn French and German, in order to read the published scientific papers of Europe, and the emphasis on experimental and laboratory education.[50] This school of thought is distinct from the idea of creating "practical farmers" because, rather than educating farmers at these new colleges, this group wished to educate people who would themselves become scientists who would in turn disseminate their knowledge to farmers. Therefore, in this system, the education of farmers would be done more indirectly through the educating of people who would then educate farmers.

The passage in 1887 of the Hatch Act put an end to these debates. As Williams describes, "[t]he Hatch Act was a masterpiece of political compromise."[51] In March 1887, the bill proposed the year before by William Hatch, a Representative from Missouri, was signed into law. Specifically, the Hatch Act authorized the federal government to fund experiment stations to be associated with each of the land-grant colleges, with the stipulation that the experiment stations were required to publish periodical bulletins detailing their work and addressing the concerns of farmers in their states.[52] However, many of the desires of groups from all sides of the debate over the means of education would be addressed by this legislation as well. For example, as Charles

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[48] Marcus, "The Ivory Silo," 29-30.
[49] Ibid., 31.
[50] Ibid., 31.
[51] Williams, *Federal Support,* 88.
[52] Bezilla, *College of Agriculture,* 47.

Rosenberg explains, "The [experiment] stations would help the farmers adjust to an increasingly competitive world market, would rationalize and systematize his operations."[53] As seen earlier, farmers wished the agricultural schools to teach them more systematic ways of farming to increase their farm's profit. Williams idea of compromise is then highlighted by the fact that these principles would be taught using scientific methods, a primary desire of the agricultural scientists. However, it is certainly true that agricultural scientists received more of what they desired than did the farmers.[54] And though agricultural scientists generally won out, the Hatch Act ultimately specifically advanced the cause of those wishing for experimentation to be a key part of education and college function. This is due primarily to the fact that the Hatch Act authorized the federal government to fund experiment stations to carry out agricultural research at the land-grant colleges.[55] As mentioned briefly before, experiment stations had long been a staple of European agricultural science – Evan Pugh had worked at the Rothamstead experiment station – but very few had been created in the United States. And those that did exist had very limited scope in what the work they performed, mainly dealing with the testing of fertilizer samples as a means of meeting state regulatory laws.[56] Many of the newly created experiment stations would take on this role as well, but the new opportunity presented by the Hatch Act would allow them to begin taking on a broader role and often become involved in the education provided at land-grant colleges. However, even if the Hatch Act more clearly defined the type of education to be provided at the land-grant institutions, namely one associated with experimentation and agricultural science, the land-grant movement was far from over.

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[53] Charles E. Rosenberg, "Science, Technology, and Economic Growth: The Case of the Agricultural Experiment Station Scientist, 1875-1914," *Agricultural History* 45, no. 1 (1971): 2, *ProQuest,* Online (accessed on 20 July 2018).
[54] Williams, *Federal Support,* 88.
[55] Bezilla, *College of Agriculture,* 47.
[56] Ibid., 42.

Nonetheless, the newly created research stations helped land-grants schools find new purpose and helped Americans better understand the necessity of supporting those institutions.

The first experiment station to be founded in the United States was the Connecticut station, founded in 1875, twelve years before the passage of the Hatch Act. A few years later, however, an effort was made to establish one in Pennsylvania.[57] A year before the founding of the Connecticut station, the Agricultural College of Pennsylvania underwent another name change under the direction of president James Calder to become the Pennsylvania State College, soon there-after often referred to simply as Penn State.[58] The years surrounding the name change saw a slow drift away from the missions of the land-grant colleges. Things began to turn around, however, when George W. Atherton was selected as president of the College in July 1882.[59] Almost immediately, Atherton began work to correct the mistakes made by the presidents who had served since Pugh's death in 1864.

One area the new President focused on was fulfilling the obligations Penn State owed to the farmers of Pennsylvania. The prime example of an initiative in this realm was his working to establish an experiment station at Penn State. Approached by professor of agriculture Whitman Jordan about the idea, Atherton was very much in favor of the proposal. Jordan had worked at the Connecticut station, and wished to establish that same level of research at Penn State. Atherton was able to convince the Pennsylvania State Board of Agriculture to propose a bill which would give the necessary funding to the school to establish that station, but Governor Robert Pattison vetoed the bill in July 1883.[60] Despite being unsuccessful at the state level, however, Atherton would later become critical in the passage of the federal legislation of the

[57] Bezilla, *College of Agriculture*, 42.
[58] Ibid., 26.
[59] Ibid., 41.
[60] Ibid., 42-44.

Hatch Act.[61] Once the legislation was passed, and Penn State received funding to create its experiment station – which it would do in 1887[62] – the experiment station at Penn State would soon lead the charge in the performance of highly influential agricultural scientific research in the United States. This would be thanks, in large part, to the first director of the Penn State experiment station, Henry Prentiss Armsby.

Armsby was born in Northbridge, MA on September 21, 1853. His family moved twice while he was young, and as such he received his elementary education first in Whitinsville and later in Millbury.[63] In 1868, at the age of 15, he entered Worcester Polytechnic Institute and three years later graduated with a Bachelor of Science. In 1872 he began graduate studies at the Sheffield Scientific School at Yale College, and graduated in 1874 with a Bachelor of Philosophy.[64] The following year, Armsby traveled to Europe and spent a year working at a German Agricultural Experiment Station just outside of Leipzig. While here, Armsby would have encountered the digestion and energy metabolism experiments being carried out at the experiment station with the use of a Pettenkofer respiration apparatus. This almost certainly influenced the ultimate path of Armsby's career.[65]

Upon returning to the United States in 1876, Armsby jumped around between many of the pre-Hatch Act experiment stations across the country. Significantly, Armsby worked at the experiment station in Connecticut and he received his Ph.D. from Yale University in 1879. From

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[61] One Senator, during debate of the Hatch Act is quoted as referring to "the gentlemen who have devoted special attention to this subject, including and chief among whom is Mr. Atherton," as explained by Williams, *Federal Support,* 88.
[62] Bezilla, *College of Agriculture,* 47.
[63] Raymond W. Swift, "Henry Prentiss Armsby," *The Journal of Nutrition* 55, no. 1 (1954): 3, found in Collected Papers of the Animal Nutrition Institute, Eberly Family Special Collections Library, The Pennsylvania State University, University Park, PA.
[64] Though it's rather clear that this Bachelor of Philosophy degree did entail some scientific education, it is intriguing to note, as will be discussed in a later chapter, that even in his first two degrees, Armsby could be considered a philosopher-scientist! Swift, "Henry Prentiss Armsby," 3.
[65] Robert L. Cowan, "Henry Prentiss Armsby, 1853-1921: A Brief Biography," *The Journal of Animal Science* 66 (1988): 1837, *JSTOR,* Online (accessed on 29 November 2017).

1883 to 1887 he served as the Associate Director of the Agricultural Experiment Station at the University of Wisconsin.[66] All of this experience prepared Armsby for his eventual position at the Pennsylvania Agricultural Experiment Station, but it was his publishing of his *Manual of Cattle Feeding* in 1880 that propelled his name to the forefront of agricultural research.[67]

Further, upon passage of the Hatch Act, while he was at Wisconsin, Armsby wrote a letter to Atherton in March of 1887 congratulating Atherton on the success of his efforts regarding the bill. Armsby also noted that the creation of a new experiment station at Penn State may create a need for a director of that station and suggests, “If, therefore, you should be consulted as to the filling of such a position and should feel inclined to recommend or suggest me, you might do me a service, and would in any case have my thanks.”[68] Perhaps due to this letter, and certainly due in large part to the name he had made for himself with the work he had done across the country in promoting and participating in the work of various experiment stations, Armsby was chosen in 1887 to be the first director of the Pennsylvania Agricultural Experiment Station at the Pennsylvania State College.[69]

During his time at these various experiment stations, and certainly once he began work in Pennsylvania, Armsby likely would have been exposed to the various social and economic factors that influenced the work done at the new experiment stations. One of these factors was the influence of farmers on the work being done at the experiment station, as described in a 1971 article written by Charles Rosenberg that takes the agricultural experiment station scientist of the

[66] Cowan, “Armsby”, 1838.
[67] Swift, “Armsby,” 4.
[68] Henry Armsby to George Atherton, March 4, 1887, Henry Armsby Papers, Pennsylvania State College of Agriculture, Pasto Agricultural Museum, State College, PA. The closing of this letter is also quite interesting as Armsby tells Atherton, “I am too comfortably situated here to wish to make any very active efforts to obtain a new position, but I should not be sorry to have my name mentioned for a desirable one, even should nothing further come of it.” Then just before closing the letter remarked, “Kindly consider this letter as strictly confidential.”
[69] Swift, “Armsby,” 6.

late 19th century as a case study for science's role in economic growth.[70] Rosenberg discusses many expectations that farmers had for experiment stations, but the most compelling description of their expectation is summed up by Rosenberg as being "to perform the experiments which the individual farmer lacking time and opportunity could not."[71] This expectation likely stemmed from the agricultural depression which existed in the decades prior to 1900, and this often led to experiment station staff being tasked with relatively more mundane tasks such as testing chemical fertilizers and constantly being plagued with questions from their local farmers, often taking scientists away from what they truly wished to do.[72] Knowing that pleasing these farmers was key to their continuing to receive support, however, experiment station scientists were forced into a role in which they could both pursue their own goals while also pleasing the public. Rosenberg describes this position by arguing that experiment station staff, and especially station directors, had to fill two roles. These roles were "working scientist" and "research-entrepreneur."[73] Rosenberg explains further that station directors "were forced to mediate between the world of science on the one hand and, on the other, the social and economic realities of a particular state constituency."[74] These are just two of the multiple roles in which experiment station staff found themselves operating at this time, and more of these roles will be discussed in later chapters, but these particular roles perhaps best highlight the balancing act experiment station directors, Armsby included, often had to perform in order to one day be able to pursue their own goals for the newly created research stations.

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70 Rosenberg, "Science, Technology, and Economic Growth," 1.
71 Ibid., 2.
72 The role of the agricultural depression in discussed in Bezilla, *College of Agriculture*, 90. The mundane roles of experiment station staffs prior to 1900 is discussed in Rosenberg, "Science, Technology, and Economic Growth," 3.
73 Rosenberg, "Science, Technology, and Economic Growth," 6.
74 Ibid., 6.

Another group which frequently influenced the work of experiment station directors was that of the college presidents. Often, experiment stations did not fit perfectly into the administrative structure of their respective universities, and this sometimes led to conflict between university personnel and experiment station scientists.[75] In the case of Penn State, Armsby and Atherton disagreed over whether experiment station scientists should be expected to teach in addition to performing their research. Though Atherton believed they were expected to, Armsby believed they should devote their time primarily, perhaps exclusively, to their research.[76] Armsby, like many other scientists, believed their research work to be of the utmost importance. However, they also understood that their unique positions in society and in their respective universities required them to perform in various roles in order to solidify their positions and help them to eventually achieve their ultimate goals.

In the case of Armsby, though he and Atherton had disagreements over the role of the experiment station and the responsibilities of the station staff, Atherton was consistently supportive of the work being done at the station.[77] In 1895, Atherton appointed Armsby to be the dean of the newly organized School of Agriculture.[78] Armsby retained his position as director of the experiment station, however, and was therefore able to continue the critical work being done there. The primary focus of Armsby's research was in the field of animal nutrition. He did not believe the current standard for determining a feed's nutritive value was an acceptable method of evaluating the feed and consequently worked to find a better way of measuring the relative value of given feedstuffs.[79] The specifics of this work will be discussed in a later chapter, but the

[75] Rosenberg, "Science, Technology, and Economic Growth," 3-4.
[76] Bezilla, *College of Agriculture,* 48-50.
[77] Ibid., 50.
[78] Ibid., 58.
[79] Ibid., 71.

important aspect of this research for the time being is best explained by Bezilla when he describes Armsby's work as "the only significant fundamental research at the station."[80]

The importance of his work led the United States Department of Agriculture (USDA) Bureau of Animal Industry, in 1899, to offer Armsby funding to build a respiration calorimeter at the Penn State Experiment Station.[81] This funding coincided with the end of the nationwide agricultural depression, so Armsby, and experiment station scientists across the country, could now focus on "more fundamental, long-range investigations" rather than simply seeking to resolve daily problems brought to them by farmers.[82] Therefore, unfettered from the peskier side of his work, Armsby could pursue his more fundamental research goals. And once experimentation began in the respiration calorimeter in 1902, Armsby's work only continued to increase in its success and renown across the nation. Soon after the construction of his respiration calorimeter, Armsby even received permission to step down as dean of the School of Agriculture in order to focus more on his research.[83]

Following this administrative change, and especially after the death of Atherton in 1906, Penn State underwent a period of trouble similar to the troubles experienced before Atherton came to the school. Despite an increase in enrollment at the college, the biennial funding from the Pennsylvania state legislature had not increased since the early 1890s. It was also difficult to find a replacement for Armsby as dean of the School of Agriculture because of low faculty morale at the time.[84] Luckily, in 1907, even amidst this strife, the Board of Trustees hired

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[80] Bezilla, *College of Agriculture*, 71.
[81] Ibid., 71.
[82] Ibid., 97. It is worth noting that this is not to say agricultural scientists never wished to help farmers with their problems. However, many agricultural scientists believed that focusing on more fundamental issues of agricultural science would lead to better resolution of problems, rather than just quick fixes.
[83] He did however agree to remain temporarily until his replacement was found, as described in ibid., 82.
[84] One intriguing cause of this low morale was the "Great Strike" of 1905 during which students skipped class for nine days as a reaction against a decision by the faculty to shorten their Thanksgiving Break. Though the situation

Thomas Hunt, a former Penn State professor of general agriculture from 1891-1892, as the new dean of the School of Agriculture.[85] After leaving Penn State in 1892, Hunt moved to Ohio State University and helped strengthen their struggling school of agriculture. Being frustrated with the impossibility of receiving a pay raise at Ohio State, he returned to the east coast, first to Cornell and ultimately back to Penn State.[86]

Much like his work at Ohio State, Hunt would go on to help revitalize the School of Agriculture at Penn State. But he was also very careful about not pushing too far in his reforms. As he explained early in 1907, "I believe in evolution, not revolution."[87] The first of his initiatives was the division of the school into various departments, rather than offering a single curriculum in general agricultural education as it had long done. Hunt believed this would not only give more variety to prospective students, but would also help to promote the strengths of the faculty in the school, as many of the new departments had a corresponding faculty member who was an expert in that field.[88]

In addition to this reorganization, the other major initiative begun by Hunt was the establishment of an agricultural extension department. Alva Agee, who worked at the experiment station in Ohio, was hired to head up this department.[89] As explained by Kevin Curry, a current faculty member in the Penn State Agricultural Extension Department, the question land-grant institutions asked and answered with agricultural extension was: "how do we get this research-based information to farmers?"[90] Curry further explained that land-grant institutions had been

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was resolved, many faculty members felt they had been cheated in the compromise. This trouble, and the others mentioned, are explained in Bezilla, *College of Agriculture,* 82.
85 Ibid., 82.
86 Ibid., 82.
87 Ibid., 84.
88 The departments created from this reorganization were "agricultural chemistry, agronomy, animal husbandry, dairy husbandry, forestry, horticulture, and plant pathology" as described in ibid., 84.
89 Ibid., 87.
90 Oral interview of Kevin Curry, interviewed by Joshua Tonkel, 26 May 2018, University Park, Pennsylvania.

created with the 1862 Morrill Act and that a tradition of agricultural research was emphasized with the 1887 Hatch Act, but neither of these directly addressed the issue of bringing education and information to the farmers who did not attend the land-grant institutions.[91] Agricultural Extension work developed to address that concern, and Alva Agee was able to advance these goals through a number of initiatives during his time at Penn State.

One example of these initiatives was his striking a deal with the Pennsylvania Railroad to bring trains to the college throughout the year to show Pennsylvania farmers, many of whom lived within a day's travel, the nature and importance of the work being done at Penn State.[92] Agee quickly realized that it would be even more efficient if there existed, alongside this bringing of farmers to the college, a system of bringing the college to the farmers. In order to accomplish this, in 1908, the first train carrying agricultural faculty left State College to begin demonstrating the work of the school to the farmers in their own environments.[93] These measures allowed for highly successful communication between Penn State and Pennsylvania farmers. In 1910, Agee reported that the outgoing trains alone had allowed the college to reach around 50,000 people in 40 different counties, greatly increasing the visibility of the college among farmers.[94]

The efforts of Thomas Hunt in reorganizing the School of Agriculture and demonstrating its importance to farmers throughout Pennsylvania quickly paid off by bringing new life to the school. Between the 1900-1901 school year and the 1905-1906 school year, the undergraduate population of the School of Agriculture had only increased from ten to twenty-nine, well behind

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[91] Oral interview of Kevin Curry, interviewed by Joshua Tonkel, 26 May 2018, University Park, Pennsylvania.
[92] Bezilla, *College of Agriculture*, 95.
[93] Ibid., 95.
[94] Ibid., 96.

the average of other land-grant colleges at the time.[95] However, following Hunt's and Agee's reforms of 1907 and 1908, the undergraduate population in the School of Agriculture had reached 500 by the 1911-1912 school year.[96] Clearly Hunt was able to utilize the strengths of existing agricultural faculty, supplement that strength through the hiring of new and equally impressive faculty, and revitalize the School of Agriculture which had suffered in the years prior to his hiring. Under the leadership of Hunt, the School of Agriculture saw growth like it had never before experienced.

This trend held true for Penn State more broadly as well, and these accomplishments would carry Penn State successfully into the 20th century.[97] Much like at Penn State, many land-grant colleges across the nation received a new sense of purpose following the Hatch Act of 1887, but, again like Penn State, many still had specific details which would need to be ironed out through the work of specific innovators at those institutions. However, the more important impact of the Hatch Act was that the funding for research at experiment stations allowed the land-grant institutions to begin catching up with their European counterparts, and the necessity of disseminating the findings of that research helped the land-grant colleges grow more fully into their intended mission and role in society.

Returning again to the list offered by Roger Williams, the most compelling single factor from Williams' list – if only because it reasonably encompasses the effects of the other factors in the list – is that "educational and political innovators" wished to find a way of preparing America for the changes associated with industrialization.[98] As seen above through the specific example

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[95] Undergraduate population found in Bezilla, *College of Agriculture,* 84. National trend found in Bezilla, *College of Agriculture*, 90.
[96] Ibid., 91.
[97] Ibid., 81.
[98] Williams, *Federal Support*, 11.

of Penn State, the influence of many men, including legislators such as Justin Morrill and William Hatch, educational leaders such as George Atherton and Thomas Hunt, and agricultural scientists such as Evan Pugh and Henry Armsby, helped create the land-grant movement and provide the necessary push to carry the movement successfully into the 20th century. It may be hard to determine the most important factor of this development in American higher education, but it is clear that many different factors contributed to the movement. Concerns over industrialization and its impact on agriculture, desires to create practical education and scientifically oriented education, as well as federal legislation supported by men who wished to address these concerns all played a role in the beginnings and growth of the land-grant movement, and this movement would forever change the landscape of American higher education.

CHAPTER 2

Philosopher-Scientists and Their Roles

The ultimate success of the land-grant movement relied heavily on key figures who skillfully managed to steer public sentiment and political legislation in such a way as to achieve their goals for a new system of higher education. In order to successfully navigate the socio-political climate of the 19th century, these leaders needed to have a broad knowledge base and skill set, often outside of their primary professions. Similar to the "gentleman-farmers" who were early advocates for agricultural reform, even though they themselves were employed as lawyers or bankers, the leaders of the land-grant movement exhibited unique characteristics which may seem outside of their expected realm of expertise. This was especially true for the scientists involved in the land-grant movement. Rather than simply trying to advocate for the educational reform which was central to the movement, these scientists also sought to legitimize their work and convince the public of their personal opinions regarding the nature and purpose of scientific research.

Partly due to that added responsibility, many American scientists of the late 19th and early 20th centuries could be classified as "philosopher-scientists." This classification serves to highlight the unique character of scientists at the time in three key ways. First, it pays homage to the nature of education which that generation of scientists received. As Bryan McDonald, an historian at Penn State, points out, many scientists of the late 19th and early 20th century were classically trained in Latin, Greek, and the humanities.[99] As mentioned in the previous chapter, this resulted from the early American universities' focus on an education which would create virtuous citizens, as defined by classical ideals. This style of education contributed to a broad

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[99] Oral interview of Bryan McDonald, interviewed by Joshua Tonkel, 14 November 2017, University Park, Pennsylvania.

knowledge base for these scientists and was therefore conducive in the formation of this generation of philosopher-scientists. It is also worth noting that in the aforementioned early-American curriculum, scientific education would have played a minimal role, if any at all. This resulted in many aspiring scientists travelling to Europe after their initial education to receive a more science-based education at European institutions. However, as some of these scientists returned to the United States and began advocating for more scientific education in their home country, the skills and knowledge they received from their more classical education served a vital function in their advocacy efforts. Their exposure to multiple disciplines during their education led to their accumulating many skills which likely contributed to the variety of roles philosopher-scientists found themselves filling during their careers.

In addition, the term philosopher-scientist hearkens to the natural philosophers involved in scientific endeavors in the pre-modern period. Though a direct comparison between philosopher-scientists and natural philosophers is not intended, the similarity in name does help temporally place philosopher-scientists within the historical progression of their given field. In his book on the history of natural philosophy, historian of science Edward Grant makes the argument that the development of modern science relied on the convergence of natural philosophy with mathematical sciences, as they existed in medieval Europe.[100] This provides the intellectual history behind the theory of modern science, but before the institutionalization of science – another key aspect of modern science – could occur, a period of legitimization was required for each scientific field. For the field of agricultural science, this period of legitimization coincided and corresponded with the land-grant movement of the mid- to late 19th century. As discussed in the previous chapter – and as will be discussed further below – the land-

[100] Edward Grant, *A History of Natural Philosophy: From the Ancient World to the Nineteenth Century* (Cambridge: Cambridge University Press, 2006), 323, *ProQuest*, Online (accessed on 10 January 2019).

grant movement sought to provide universal education for the industrial and working-class citizens of the United States. Because of that motivation, philosopher-scientists also displayed pronounced interest in the idea of democratizing the results of their scientific work while also seeking to create a sort of research-elite class of research scientists. These efforts were critical in the legitimization of scientific research in this time period, making philosopher-scientists critical in that process. In this way, the philosopher-scientists around the turn of the 20th century were no longer the natural philosophers of pre-modern science, but they could also not quite be considered the full embodiment of modern scientists. Therefore, the designation of philosopher-scientist serves to demonstrate the important transitional role the scientists of this period played.

Finally, this term takes advantage of the Greek *philosophia*, love of knowledge, in an effort to emphasize the broad academic understandings, especially those outside the realm of exact sciences, which characterized scientists at this time. Philosopher-scientists therefore are perhaps primarily characterized by their appreciation for and utilization of broad knowledge. This broad knowledge base also seems to have led these philosopher-scientists to employ a broad long-term vision in relation to the impact of their work. Granted, most modern scientists certainly possess broad visions related to their research as well, but they may not expound much on that vision within their writings. However, philosopher-scientists never shied away from expressing the long-term impact they saw their work having. Further, the two aforementioned characteristics of philosopher-scientists play into this aspect. The more classical education these philosopher-scientists received certainly would have helped instill their interest in a broad knowledge base. Also, the process of legitimizing their work would have required a diverse skill set and a long-term vision in order to succeed. Examples of the manifestation of these traits will be discussed below, but suffice to say, an appreciation for and utilization of broad knowledge and the possession of a broad vision of the impact of their scientific work are primary characteristics of philosopher-scientists.

Henry Prentiss Armsby, the animal nutritionist who became first director of the Pennsylvania State College Agricultural Experiment Station, is a prime example of a philosopher-scientist. Alongside his work as an agricultural scientist, Armsby displayed an understanding of non-scientific academic disciplines and used that broad knowledge base as a political player, public servant, and educational innovator. Each of these roles proved critical in Armsby's effort to craft scientific education in the way he thought best and obtain support for his own research through demonstrating its legitimacy and importance. However, Armsby is certainly not the only example of a philosopher-scientist from around the turn of the 20th century. The challenges he faced were faced by other agricultural scientists across the country at the time as well as many other scientists working in other disciplines also seeking to legitimize their fields. Three specific scientists, Wilbur O. Atwater, Eugene Davenport, and Ellen Swallow Richards, fall into this categorization. In the following chapter, each of these individuals will be compared with Armsby to demonstrate the extent to which Armsby worked in the three aforementioned directions in an effort to provide a clearer picture of the many dimensions of Armsby's career.[101]

Wilbur O. Atwater: Political Player

In 1869, Wilbur O. Atwater received his doctorate degree in chemistry from Yale University. Like many scientists of his era, he then travelled to Europe to study for two years in

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[101] In this comparison, care will be taken to portray the three Armsby peers in an appropriately well-developed manner, but as the prime objective of this work is to fully develop the picture of Armsby, certain discretionary decisions must be made regarding what aspects of their careers to highlight in their respective comparison to Armsby. Therefore, it is urged that the reader understand that each of these comparative characters each deserve full treatments of their own but that the pictures presented here serve the primary purpose of drawing out key aspects of Armsby's career.

Germany. Here, Atwater experienced the success of a university system supported by the state in a nation which had become the center of research for the world.[102] When he returned to the United States, though work had recently been done to move American higher education in a similar direction, it was nowhere close to being fully developed.

After spending time in various teaching positions, Atwater ultimately returned to Connecticut when he was hired as professor of chemistry at Wesleyan University in 1873. Then, as mentioned in the previous chapter, in 1875 the first agricultural research station was founded in Connecticut. Atwater was named director of this facility, and much of the work of the station was performed in his lab at Wesleyan.[103] This station was founded using private donations, and Atwater quickly understood that finding more funding for the research station would be necessary for the continuation of his work there. This need provided the opportunity for Atwater to demonstrate his aptitude for what could be considered his most important non-scientific work – namely, getting funding for the work he wished to perform. This effort began as early as 1878 when Atwater received money from the United States Fish Commission and the Smithsonian Institute to begin a "comprehensive nutritional analysis of foods grown in the United States."[104] Atwater then directed his attention toward uncovering human nutritional requirements, but he realized that even with the funding he was now receiving, he did not have the support necessary to carry out the tests required for this research. However, Atwater soon used his political savvy to form a key alliance which would help advance his cause.

In 1885, a political Boston industrialist named Edward Atkinson approached Atwater to get some information for a paper Atkinson wished to write for the American Association for the

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[102] Naomi Aronson, "Nutrition as a Social Problem: A Case Study of Entrepreneurial Strategy in Science," *Social Problems* 29, no. 5 (1982): 475, *JSTOR*, Online (accessed on 30 November 2018).
[103] Ibid., 475.
[104] Ibid., 475-476.

Advancement of Science.[105] This relationship ultimately led to Atwater associating with Carroll D. Wright, who worked for a number of governmental labor agencies. Atwater's connection with Atkinson and Wright now opened the door to a number of opportunities. In a 1982 article Naomi Aronson describes two specific opportunities which arose from this connection: "First, it opened up new sources of funding for scientific research…Second, in response to [objections regarding the nature of his work], Atwater argued that nutrition, as an aspect of labor reform, was a moral and philanthropic issue."[106] Aronson goes on to make an excellent argument that this was the beginning of Atwater framing the issue of nutrition in terms of a social problem in an effort to legitimize the work he was doing and to demonstrate its important practical applications.

The years 1887 and 1888 saw Atwater's most important contribution to this process of legitimizing his work. In these years, he published a series of articles in *The Century Illustrated Monthly Magazine.*[107] The title of this series of articles was "The Chemistry of Foods and Nutrition," and each of the six articles contained a subtitle which highlighted the specific aspect of nutrition science which was to be discussed in that particular article. Though the majority of these articles consisted of dense scientific data regarding the underlying principles of nutrition, these articles were likely not specifically directed towards other scientific researchers. Atwater's decision to publish in *The Century*, a magazine read widely among well-to-do members of the general public, reveals some of his political strategy. But before discussion of any ulterior motives, we should first take Atwater at his word and analyze what he stated the purpose of the work to be. In one of the opening paragraphs of the first article, Atwater explained,

[105] Aronson, "Nutrition as a Social Problem," 476.
[106] Ibid., 476.
[107] It is interesting to note that these articles coincided with the same years of the passage of the Hatch Act (1887) and the establishment of the Office of Experiment Stations (1888) which is to be discussed later. Though a direct connection between these events may be farfetched, it is certainly worthwhile to contextualize these writings within the climate of these important legislative and bureaucratic efforts.

> [A]t the instance of the United States National Museum…I was led to undertake a study of the chemistry of food. This has included with other matter a series of analyses of some of our common food materials. To give some of the more practical results of this work, especially as viewed in the light of late research upon the more general subject of nutrition, is the purpose of the present articles.[108]

As explained here, Atwater's primary purpose appears to have been to convey the state of nutrition research to the general public. Further, because Atwater was essentially the only American scientist working on human nutrition at the time, he certainly seemed to have been the right choice for writing these articles, and the depth of knowledge conveyed in the dense discussions confirms that supposition. However, in the fifth article of the series, the tone shifts.

In this fifth article, entitled "Pecuniary Economy of Food," Atwater primarily spoke at length regarding how society should strive to uncover the cheapest nutritionally sufficient diet in order to better the conditions of life in America. He argued that though many people viewed the food "which has the finest appearance and flavor" as being the best, this was often the most expensive choice, and should therefore not be the primary desire of those with lower incomes. Rather, he argued that everyone should desire the cheapest food, which he specifically defined as being "that which supplies the most nutriment for the least money."[109] Atwater argued in this article that in order to reduce waste and in order to better help the poorer people of society, the pursuit of cheap but nutritional food was the proper solution.

The key part of this article, though, is found in the last paragraph. Atwater understood that in order for his plan, as described above, to be successful, people would need to be educated about nutrition. In the final paragraph, he acknowledged the difficulties of achieving this, as, in

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[108] Wilbur O. Atwater, "The Chemistry of Foods and Nutrition I: The Composition of Our Bodies and Food," *Century Illustrated Magazine* 34, no. 1 (1887): 60.
[109] Wilbur O. Atwater, "The Chemistry of Foods and Nutrition V: Pecuniary Economy of Food," *Century Illustrated Magazine* 35, no. 3 (1888): 437.

his words, “The subject is, however, new.”[110] He argued that further research would be needed to explore this uncharted field of science, but that American scientists are currently unable to do that. He pointed out that European scientists are performing important investigations, but in the United States, “little is being done, and that little is dependent almost entirely upon private munificence for its support.”[111] Obviously this presents a problem, but Atwater was quick to provide a solution, suggesting,

> If the cost of a yacht were invested in appliances for research in this direction, and the annual expense of maintaining it were devoted to carrying on such researches, they would bring fruit of untold value to the world, and, to the donor, the richest reward that a lover of his fellow-men could have.[112]

Based on this statement, I would argue that Atwater wished to employ these articles not only to summarize the current state of nutrition research, but also to advocate for the financial support of that research. Remembering the audience reading *The Century* and noting the choice of yacht financing as an analogy for research funding, it seems likely that Atwater wished to convince well-to-do, socially-minded Americans of the importance of his research. This theory is further supported by the fact that in 1894, only a few years after the publishing of these articles, Congress allocated $10,000 to the agricultural experiment stations for studies into nutrition.[113]

Another example of the political success of Atwater can be seen in the passage by the United States Congress of the Adams Act of 1906. This Act added to the funds granted to agricultural experiment stations in the Hatch Act of 1887, increasing the allotment from Hatch’s $15,000 per year to $30,000 under the Adams Act.[114] Charles Rosenberg suggests that the passage of the Adams Act required overcoming certain administrative challenges presented by

[110] Atwater, “Pecuniary Economy of Food,” 446.
[111] Ibid., 446.
[112] Ibid., 446.
[113] Aronson, “Nutrition as a Social Problem,” 479.
[114] Charles E. Rosenberg, “The Adams Act: Politics and the Cause of Scientific Research,” *Agricultural History* 38, no. 1 (1964): 3, *JSTOR*, Online (accessed on 30 November 2018).

the Hatch Act. These challenges were addressed through the creation of the Office of Experiment Stations in 1888 to act as a division of the USDA tasked with coordinating relationships between experiment stations and the USDA. Rosenberg argues that the work of the Office of Experiment Stations provided a "surprisingly successful" solution to the problems it sought to remedy.[115] He attributed this success to the efforts of "three men who shared a remarkable practicality and an equally remarkable clarity of purpose; namely, Wilbur O. Atwater, Alfred C. True, and Edward W. Allen."[116] The first two men in this list are most pertinent to the present section. Atwater served as the first director of the Office of Experiment Stations, but only served for two years. Hence, his influence on the Office was more indirect. When Atwater began his work in Washington, he brought along a colleague from Wesleyan University's Classics Department. That colleague was Alfred C. True, who would serve as the director of the Office of Experiment Stations from 1892 to 1915.[117]

True would play a number of important roles while he served as director, but one of the most important was the influence he had over the creation and institution of the Adams Act. Soon after the passage of the Hatch Act, it became clear that the wording of the act did not allow the Office of Experiment Stations to have much control over directing the work of stations. Specifically, it was unable to direct research towards "abstract investigations" aimed at "the advancement of scientific knowledge." Because of that, work at experiment stations often focused on addressing the practical concerns of the station's constituents.[118] Many scientists at the time, including Atwater and Allen, wished to see a push for more purely scientific research,

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[115] Rosenberg, "The Adams Act," 3.
[116] Ibid., 3.
[117] Ibid., 4.
[118] Ibid., 4-5.

but they realized the Hatch Act was not able to accomplish that goal.[119] A. C. True also recognized these difficulties, and it was likely this recognition that prompted True to write the original draft of the Adams Act which, in Rosenberg's words, "not only increased the financial resources of the stations, but in its specification of 'original investigations' provided the administrative leverage with which to control the expenditure of these funds."[120] Further, True utilized the Office of Experiment Stations to lobby for the passage of the Adams Act, which was ultimately a successful endeavor.[121] This success demonstrates that Atwater, through his grooming of True for the directorship of the Office of Experiment Stations, was able to politically maneuver situations, even if indirectly, to an end he desired; in this case, he received further funding and influenced the direction of research at other experiment stations.

Overall, as demonstrated by his creating politically beneficial relationships, his publishing of a series of articles in *The Century*, and his indirect influence over the passage of the Adams Act, Atwater utilized a number of political maneuvers to help demonstrate the importance of his nutrition research and to receive funding for that research. While never sacrificing the quality of his research, as can be seen in the depth of knowledge contained in the *Century* articles, Atwater also made sure to publicly portray his work as a social problem in need of solving. This is not to say that his concern was insincere, however, as he continued to devote his life to helping educate the poor and working classes about proper nutritional practices. But rather, his appeals to politicians and wealthy Americans demonstrated a political savviness which helped him advance his scientific work. All of these actions and characteristics suggest that Atwater certainly fits the mold of a philosopher-scientist.

[119] Just as Atwater and Allen pushed for pure science, Henry Armsby did as well. In fact, as argued in the next chapter, Armsby appears to have believed in the sanctity of pure science to an even greater extent than did Atwater.
[120] Rosenberg, "The Adams Act," 5.
[121] Ibid., 5.

Ellen Swallow Richards: Public Servant

Ellen Swallow was born on December 3, 1842 on a small family farm near Dunstable, Massachusetts. Inheriting a familial tendency for poor health, a doctor prescribed that she spend ample amounts of time outside to receive the then common recommendation of "fresh air and plenty of sunshine."[122] The land around her family's farm did appear to help Ellen with her early ailments, but this time spent outdoors likely also fostered her passion for science and her appreciation for the natural world. Always an avid learner, Ellen's parents educated her from a young age in a variety of subjects such as history, logic, mathematics, and literature.[123] Seeing her aptitude toward learning, her parents soon realized, in one biographer's words, that Ellen's needs had changed "from body to mind," and so they moved to Westford in 1859 where seventeen-year-old Ellen was enrolled in Westford Academy to begin a more formal education.[124]

The education she received at this school mirrored the classical style of education prevalent at the time, as it consisted of foreign language study and an emphasis on the Greek and Roman classics. During this time, and after she graduated from Westford, Ellen also worked for her father in his general store. Here, she again demonstrated her intellectual ability and curiosity as she was noted to have been deeply interested in the lives of the store's customers, particularly when it came to their knowledge of food.[125] Unfortunately, she also found herself becoming increasingly depressed as there was no opportunity available for her to satisfy her desire of continuing her education. That changed, however, in 1865 when she learned of Matthew

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[122] Robert Clarke, *Ellen Swallow: The Woman Who Founded Ecology* (Chicago: Follet Publishing Company, 1973), 6.
[123] Ibid., 8.
[124] Ibid., 8.
[125] Ibid., 9.

Vassar's opening of a school to provide women with higher education. In 1868, she enrolled in Vassar College, as the school was known, and left her family home to pursue her studies.[126]

At Vassar College, Ellen finally found the opportunity to study the science she had always loved but in which she had never received formal education. Two particular science professors at Vassar College, Maria Mitchell and A.C. Farrar, left an impression on Ellen's life and career. Mitchell taught astronomy, and Ellen was almost immediately drawn to her and her studies. Seeing a woman so advanced in her field and teaching at such a level likely helped kindle Ellen's desire to pursue a similar career track. Farrar was a professor of chemistry, and it was his work that ultimately drew Ellen firmly into the field which would define her career. As one biographer explains, in the struggle between astronomy and chemistry within Ellen, "chemistry slowly gained on the ethereal outer world because it allowed for Ellen Swallow's obsession for practical application of knowledge."[127] Ellen's gravitating towards chemistry, and the content of her later writings as discussed below, revealed that she, like many philosopher-scientists, was deeply concerned with the impact she and her work could have on the world.

Eventually, after graduating from Vassar, Ellen began applying for various jobs in the hopes of working as a chemist, but was never offered a position. She did, however, receive advice from one company that she apply for admission to the young Institute of Technology in Boston, a school which would later be known as The Massachusetts Institute of Technology. Though no woman had ever been admitted before, recommendations from Mitchell and Farrar convinced the admissions board at MIT to admit Ellen, and she began her studies there in 1871 and graduated with a degree in Chemistry in 1873, widely believed to be the first American

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[126] Clarke, *Ellen Swallow*, 13-14.
[127] Ibid., 17.

woman to earn a college degree in science.[128] During her time at MIT, she met professor of mineralogy, Robert Richards, whom she would marry in 1875.[129] More importantly, however, due to her status as the first woman admitted to the institution and the remarkable work she performed while a student there, Ellen quickly became widely renowned, eventually being known internationally as America's First Lady of Science.[130]

Her career contained numerous examples of her success as a scientist, but her endeavors late in life to advocate for her self-created discipline of Euthenics offers the best example of Ellen as a philosopher-scientist. As Robert Clarke describes in his 1973 biography of Ellen Swallow, the common sentiment among scientists at the turn of the 20th century was that all societal problems could be traced back to heredity – namely, any people who were "poor, ignorant, or had 'criminal tendencies'" were only that way "because they were born that way."[131] Therefore, since those bad qualities were inherited, the best way to rid society of those problems would be to follow nature's pattern of ridding populations of undesirable qualities through breeding. The application of that intentional breeding within the human population was known as eugenics.[132] The modern reader immediately understands the falsehood and danger of those assertions, but when Ellen proposed that these ideas were incorrect, there were virtually no scientists who would have agreed with her. But never being one to back down, Ellen pursued her beliefs and began advocating for her newly created field of Euthenics. In reaction, many scientists began accusing Ellen of now being a sociologist, a field then much disliked by scientists in other more fully developed fields. But as Clarke explains, instead of pushing back

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[128] Clarke, *Ellen Swallow*, 25.
[129] Ibid., 55.
[130] While still a student at MIT, Ellen was asked by Prof. William Ripley to assist him in a series of water quality surveys. This experience not only allowed Ellen to demonstrate her scientific ability, but also further directed her down the path of using science for societal benefit as described in ibid., 38-43.
[131] Ibid., 194.
[132] Ibid., 194.

against the accusations, Ellen "enigmatically explained that her desire to reduce human suffering had drawn her to science in the first place; she wanted to help, to be useful. If that made a chemist a sociologist, so be it."[133] Clearly, for Ellen, the scientific advancement was closely tied with the bettering of society, and she would unwaveringly work to use science to help society.

The ideas of Euthenics, this culmination and prime example of Ellen's social application of scientific work, were most completely developed in her 1910 book, *Euthenics: The Science of Controllable Environment*. In the foreword to that book, she defined the term Euthenics, a word of her own creation, as "the betterment of living conditions, through conscious endeavor, for the purpose of securing efficient human beings."[134] This definition alone reveals the public application Ellen saw for her work. In a time when scientific principles were employed with the hope of increasing efficiency, be it in a factory's production or a farm's yield, when Richards talks of creating "efficient human beings" it is implicit that she means to use scientific principles to improve humans the same way others sought to improve factories or farms. Richards also took time to highlight the immediate benefit her work could have for the public through comparison of Euthenics with Eugenics. She explained,

> Eugenics is hygiene for the future generations. Euthenics is hygiene for the present generation. Eugenics must await careful investigation. Euthenics has immediate opportunity. Euthenics precedes eugenics, developing better men now.[135]

She concluded this foreword by connecting Euthenics with scientific study and explaining that the "individual must estimate properly the value of this [scientific] knowledge in its application to daily life, in order to secure efficiency and the greatest happiness for himself and for the

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[133] Clarke, *Ellen Swallow*, 193.
[134] Ellen H. Richards, *Euthenics: The Science of Controllable Environment*, (Boston: Whitcomb & Barrows, 1910), vii.
[135] Ibid., viii.

community."[136] In this section, Ellen very carefully connected her new theory of Euthenics with scientific study and argued that this scientific knowledge could then be used for helping people, which was itself a core tenet of Euthenics.

In the main text of the book, Ellen argued the scientific basis for her theory of Euthenics. For example, she explained that diseases of which "the State [had] taken cognizance and to the suppression of which it has applied known laws of science," had been controlled and greatly reduced. However, she also pointed out that "other troubles under personal control," such as kidney and heart disease, had increased in recent years.[137] She argued that if scientific principles were also applied to solving these more persistent diseases, then they too could be brought under control. Again, it must be emphasized that the theme of scientific knowledge being applied to solve problems is central to this book and to the theory of Euthenics overall. In fact, the opening line in the foreword, the first line of this book, reads, "Not through chance, but through increase of scientific knowledge…will be brought about the creation of right conditions, the control of the environment."[138] This is the key idea of Euthenics. Ellen believed that an increase of scientific knowledge would lead to a human ability to control the environment and prevent all sorts of diseases and societal problems.

As would be expected from a philosopher-scientist such as Ellen Richards, there are more than simply scientific appeals in her work. In the opening chapter, for example, Ellen made a series of economic arguments for the acceptance of her theories and adoption of her solutions. She estimated the "average economic value of an inhabitant of the United States" to be around $2,900. Multiplying that value by the 85.5 million people living in the United States at that time,

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[136] Ellen Richards, *Euthenics*, ix-x.
[137] Ibid., 3.
[138] Ibid., vii.

she essentially valued the U.S. population to be worth $250 billion. She continued by arguing that the “actual economic saving possible annually in this country by preventing needless deaths, needless illness, and needless fatigue” was over $1.5 billion. She later made a statement which revealed her reasoning for making this economic argument, explaining that these arguments had been made to insurance men, and that they were intrigued by the potential they presented. In her words, “It gave to the world what, up to that time, it had lacked – a body of powerful men who recognized that they had a financial interest in preventing the needless death of men and women.”[139] Though one may expect a moral argument to be employed in a discussion regarding the saving of lives, Ellen clearly recognized the growing industrial concern with profit potential in that time period and therefore used an economic argument to portray the necessity of solving this problem.

Another argument made by Ellen was based on the characteristic focus of this period on the issue of efficiency. As mentioned briefly above, just as industrialists sought to increase the efficiency of factory’s, nutritionists and other scientists concerned with human affairs also sought to increase the efficiency of individuals and human pursuits. Along these same lines, Ellen also argued, “The relation of environment to man’s efficiency is a vital consideration.”[140] She believed that adherence to the principles of Euthenics would lead humanity to controlling their environment in such a way that the environment would become well suited for the highest human efficiency. These two arguments serve as examples of Ellen, like many philosopher-scientists, displaying an understanding of societal trends and working her knowledge of those trends into her argument for the legitimacy of her scientific work.

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[139] Ellen Richards, *Euthenics*, 8.
[140] Ibid., 15.

An appeal towards creating a sort of research-elite is also seen in *Euthenics*. Ellen stated the purpose of the book at the end of the first chapter, explaining that it was “to arouse the thinking portion of the community to the opportunity of the present moment for inculcating such standards of living as shall tend to the increase of health and happiness.”[141] Though this seems to focus solely on that research-elite, or “thinking portion of the community,” and to some degree perhaps is does, it is important to note that Ellen was not solely concerned with that class of people. She, like all philosopher-scientists, was also deeply concerned with the betterment of individual lives. In fact, the second chapter of *Euthenics* is almost exclusively devoted to how important it is that the individual ultimately work these principles into their own lives. She said, “The knowledge that investigators are gaining in the laboratory and are trying to give to the community must be accepted and applied by the individual.”[142] She then went on to argue that for an idea such as this to take root, it simply requires a few key individuals to buy in and then return home and start applying these principles. Then, as their neighbors notice, those neighbors begin applying the principles, and then their neighbors and so on, causing the circle of adherents to grow ever wider.[143] This long process is best summed up, however, in the foreword to the book where Ellen lists three ways in which Euthenics was to be developed: (1) “through sanitary science,” which entailed scientists uncovering “the laws which make for health and the prevention of disease,” (2) “through education,” which required “various educational agencies” to bring those laws within reach of ordinary people, and (3) “through relating science and education to life,” in which the individual learns “the value of this knowledge in its application to daily life.”[144] This progression of uncovering laws of science and working to disseminate

[141] Ellen Richards, *Euthenics*, 10.
[142] Ibid., 15-16.
[143] The description of this process is found in ibid., 17-19.
[144] Ibid., ix-x.

those findings for the betterment of the public is a central mission of the land-grant colleges mentioned in the previous chapter, and philosopher-scientists believed this to be central to the mission of scientists. As seen in the example of Euthenics, Ellen Richards certainly adhered to this mission and used the broad knowledge base she acquired during her education to help legitimize the science she believed would best accomplish her mission of bettering society through science.

Eugene Davenport: Educational Innovator

Eugene Davenport was born in Woodland, Michigan on June 20, 1856. From a young age, Davenport worked on his family's farm, and as a child decided to attend college. In pursuit of this goal, he attended the Michigan State College of Agriculture and received a Bachelor of Science degree in 1878. For the next five decades, Davenport would continue to accumulate professional degrees from various institutes of higher learning.[145] After graduating college, Davenport spent ten years using his education to run his home farm and in 1888 was hired by the Michigan Agricultural College and Experiment Station where in 1889 he would be named professor of practical agriculture and superintendent of the college farm. He then spent the school year of 1891-1892 as president of the Collegio Agronomica in Sao Paolo, Brazil. Following the failure of that school, in 1895 he was hired as dean of the College of Agriculture and in 1896 as the director of the Experiment Station at the University of Illinois. As his colleague, David Kinley, wrote in an obituary for Davenport, at the University of Illinois, Davenport's "great career really began."[146]

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[145] Among these degrees were an M.S., an M.Agr., and an LL.D. in 1884, 1895, and 1907 respectively as listed in David Kinley, "Eugene Davenport," *Science* 94, no. 2431 (1941): 105, *JSTOR*, Online (accessed on 24 October 2018).
[146] Ibid., 105.

With all of his prior experience working at various agricultural institutions across the country, Davenport had likely developed certain opinions about the best way to structure the curriculum at agricultural colleges. At the University of Illinois, he would find the opportunity to enact these opinions, as, upon being hired, Davenport was first tasked with building up the College of Agriculture which was all but non-existent when he arrived. Because the school required so much work, Davenport was able to enact his philosophy of education in the school he now ran. In this pursuit, he found himself at odds with the common expectations of higher education at the time. Specifically, many people believed farmers required strictly vocational education, if they required any education at all.[147] Davenport rejected these notions believing, as Kinley explains, “that every young person should be educated both culturally and vocationally.”[148] By stating that every young person required education, Davenport echoed the growing concerns for universal education in the United States, and in his book, *Education for Efficiency*, published in 1909, Davenport develops his ideas about the nature of a new universal education system.

In the preface to this work, Davenport acknowledged that much work had been done in the effort to create universal education, but highlighted one important aspect he still found lacking. He argued, “Our education has become practically universal so far as individuals are concerned, but it is far from universal with respect to interests represented in the courses of study.”[149] Essentially, though many people had access to education, that education did not always provide the type of education that people desired. He further explained that the new

[147] Kinley, “Davenport,” 106.
[148] The issues this quote speaking of educating both culturally and vocationally were also central to a school of thought which was beginning to develop in Davenport’s time. Evan Pugh, at Penn State, held similar sentiments. In Davenport’s words, “every man needs to be efficient the vocational; to be safe and happy he needs the other.” This quote, and the quote from the text above, are both found in ibid., 106.
[149] Eugene Davenport, *Education for Efficiency* (Boston: D. C. Heath & Co. Publishers, 1909), iii, *HathiTrust*, Online (accessed on 14 November 2018).

educational system – it can be assumed he was speaking of the land-grant colleges – had begun down the path of responding to the individual's interests, but as this process was still in its early stages, there were still "new and puzzling" questions to answer.[150] These questions, according to Davenport, centered on the "real purpose of education," the "methods of instruction," and the "organization and administration of the schools."[151] He then suggested that answering these questions would likely involve "radical revisions" to the nation's understanding of educational expectations and further warned that educational leaders must not make the wrong choices at this pivotal moment, as the effects of their choices would "be felt for all time not only in individual prosperity and happiness, but throughout the entire economic, social, and political fabric as well."[152] Though these sentiments seem appropriate, and indeed in many ways they are, it must be remembered that Davenport was educated and trained to be an agricultural scientist. However, he clearly had a firm understanding of educational philosophy and the socio-economic implications of universal education, and this trait clearly places him into the category of philosopher-scientist.

Davenport closed his preface with a hint at his motivations in writing the book by remarking that among every purpose of education, "it is perfectly clear that individual and community efficiency is paramount."[153] He also maintained that this efficiency must be universal, echoing his earlier sentiments. But he now further described two specific groups in society which must have access to that efficiency – namely, "the industrial and…the non-industrial."[154] Davenport explored this idea in the main text of his book, and in the introduction,

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[150] Davenport, *Education for Efficiency*, iii.
[151] Ibid., iii.
[152] Ibid., iii.
[153] Ibid., iii.
[154] Ibid., iii.

he offers a background into the history of the movement which had begun to provide that type of universal education. In the beginning of this section, he explained that if the desire for universal education were to be pursued, there must be an education that serves "not only the exceptional five percent but the ninety-five percent of common men as well."[155] He then provided a long quote from Jonathan B. Turner, a man who could also be considered an educational innovator in his own right. Turner's quote echoes the sentiments of Davenport, and perhaps the most salient observation from this earlier innovator comes when Turner spoke of how the upper crust of society had long had institutions of higher learning dedicated to them and their interests. Turner described these institutions and asks,

> But where are the universities, the apparatus, the professors, and the literature, specifically adapted to any one of the industrial classes? … In other words, society has become, long since, wise enough to know that its teachers need to be educated, but it has not become wise enough to know that its workers need education just as much.[156]

Clearly Davenport took this statement to heart. Following this quote, Davenport provided a brief summary of the early history of the land-grant movement – a movement in which Turner was a strong leader – but explained the shortcomings of the young schools created by the Morrill Act of 1862. Specifically, he believed that though the land-grant colleges had begun accepting members of the industrial classes, the education they received was still catering to the needs of "Turner's five percent" and therefore caused the industrial class students to simply join the five-percent rather than remaining in the class of the ninety-five percent. This resulted in a situation, according to Davenport, "whereby the industrial masses remained uneducated."[157]

Davenport believed the Morrill Act of 1862 had begun to solve the problems associated with American higher-education, but had not gone far enough. He saw the Hatch Act of 1887,

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[155] Davenport, *Education for Efficiency,* 1.
[156] Ibid., 2.
[157] Ibid., 3.

which provided the funding for land-grant colleges to establish agricultural experiment stations, as an important step in the right direction, as it provided the incentive for building up the "literature of which Professor Turner so clearly saw the need" and also gave new life to the teaching at the land-grant colleges, leading to greater enrollment.[158] Despite pointing out these key steps, Davenport still took time to acknowledge the obstacles being faced by the land-grant colleges at the time of his writing. He mentioned as being especially prominent – as obstacles – the public view of education which desired different things than land-grant leaders, the lack of curricula due to the newness of the agricultural education field, and the early tendency to focus on the practical education instead of educating in scientific principles.[159]

Even in the midst of these troubles of the late 19th century, Davenport did see important progress among those involved with land-grant institutions. In relation to the problem of the lack of curricula for teaching, he described an exciting observation that "we have beheld the unparalleled prospect of a generation of self-made teachers evolving with their own experience both the matter and the methods of an entirely new educational field."[160] Davenport found hope in the progress made internally by key figures of the land-grant movement as this would lay the groundwork for future success. In addition, Davenport explained that he saw proof that these new land-grant colleges could achieve the specific aims he hoped the institutions could achieve. After first acknowledging that the public had not yet "evolved a philosophy of education adequate to the task of meeting the logical demands of a real system of universal education," he does observe that "gradually, but slowly, men have learned by experience that schooling…does not necessarily educate away from industry" and that an education appropriately adapted to the

[158] Davenport, *Education for Efficiency,* 3-4.
[159] Ibid., 5.
[160] Ibid., 5.

needs of industry "not only returns men to industrial life but also and inevitably *develops the industries* to a level that is unattainable except through education."[161] This was the core of Davenport's educational philosophy. He believed proper education of the industrial classes would benefit the people involved even as they remained in their industrial class and would also benefit the industries themselves as workers remained in those industries and could apply scientific principles to their work. Reiteration of this key fact and further confirmation of success on this front came when Davenport later explained that despite the troublesome early years of the movement, the leaders had begun to learn "two fundament facts." These facts were "that the industrial man is the better for being *suitably* educated" and "that industry develops with that sort of education of industrial people which retains them among the industries and does not drive or lead them out."[162]

Following this discussion on the state of the land-grant movement, Davenport concluded this introductory chapter by discussing what he saw as future steps for the movement. Noting the growing popularity and demand for industrial education, he knew these demands "must be reckoned with, and that at once."[163] Careful not to be swept up by this exciting growth of the movement, Davenport offered one final suggestion in this introduction which further solidifies his position as a philosopher-scientist. After asking a series of unanswered questions regarding the opening of education to all people, Davenport stated, "To answer this question safely will require the keenest insight into present conditions and the most prophetic vision as to future consequences of whatever policy shall be adopted."[164] This warning offers a succinct

[161] Davenport, *Education for Efficiency,* 4. Emphasis in the original.
[162] Following this observation, Davenport noted that agriculture in particular had become "more difficult" and therefore required these sorts of successes to continually improve that industry, as found in ibid., 5-6.
[163] Ibid., 6.
[164] Ibid., 7.

contemporary explanation of why philosopher-scientists such as Davenport were important to the land-grant movement. Anyone involved in the movement needed to understand the history of the movement and its present condition and also needed to have the ability to use that knowledge to inform their predictions about the impact of future decisions. As seen in *Education for Efficiency,* Davenport, even if he was trained and subsequently worked as a scientist, clearly had the knowledge base he believed to be critical for leaders of the land-grant movement. And it was precisely this broad knowledge base which led to his personal success and which also contributed to the ultimate success of the land-grant movement.

In addition to this book, Davenport's work at the University of Illinois and his addresses delivered to the citizens of Illinois were able to convince the public of his beliefs regarding the necessity of educating farmers and the proper methods for accomplishing this. Kinley sees the reception of funding to build up the college, to set up an experiment station, and to construct an agricultural building as proof of his success in this endeavor, but this only partially encompasses the broad success that Davenport's work had on the land-grant movement.[165] His writings were widely read, most importantly by other educational innovators in the land-grant movement. In fact, Henry Armsby quoted Davenport in an address he delivered to the American Society of Animal Nutrition.[166] This is a prime example of a philosopher-scientist being critical to the land-grant movement, and in this way, Davenport is key in understanding the uniqueness and utility of philosopher-scientists within that movement.

Further, it was this ability to successfully legitimize his desires for the college which led Rosenberg to choose Davenport as a prime example of a "research-entrepreneur." In an effort to

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[165] Kinley, "Davenport," 106.
[166] Henry Prentiss Armsby, "The Food Supply of the Future," Proceedings of The American Society of Animal Nutrition (1909), 4, found in Collected Papers of the Animal Nutrition Institute, Eberly Family Special Collections Library, The Pennsylvania State University, University Park, PA.

discuss “the behavior of scientists and scientist-administrators within an institutional context defined by social and economic factors,” Rosenberg chose agricultural experiment station scientists as prime examples of this relationship between science, economics, and society.[167] He utilized the term “research-entrepreneur” to describe the scientists’ reactions to those factors, arguing that research-entrepreneurs “were forced to mediate between the world of science on the one hand and, on the other, the social and economic realities of a particular state constituency.”[168] Satisfactorily carrying out this responsibility was obviously a difficult challenge for many scientists to accomplish, but Rosenberg chose three specific experiment station scientists who he believed best bridged and finessed this distinction, and one of these researchers was Eugene Davenport.

Rosenberg argued that Davenport was especially “successful in garnering support for his research program,” and these efforts were primarily focused towards gaining support from “agricultural producers and agriculture-related industries” outside of the university, as the university president did not seem particularly interested in supporting the agricultural college or experiment station.[169] Ultimately, these efforts proved to be successful. As Rosenberg explained, despite the challenges he faced from administrative powers, “[Davenport] could, by World War I, point to a record of outstanding growth for Illinois’ College of Agriculture and Experiment Station.”[170] This accomplishment reveals that Davenport was able to get the financial support he needed to create the kind of educational institution he described in *Education for Efficiency*, and

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[167] Charles E. Rosenberg, “Science, Technology, and Economic Growth: The Case of the Agricultural Experiment Station Scientist, 1875-1914,” *Agricultural History* 45, no. 1 (1971): 1, *ProQuest*, Online (accessed on 20 July 2018).
[168] This distinction sounds quite similar to the idea of a philosopher-scientist as discussed in this chapter, especially upon seeing Rosenberg argue that experiment station scientists were also “working scientists” on top of their “research-entrepreneur” role, as seen in ibid., 6.
[169] Ibid., 10.
[170] Ibid., 11.

this solidified Davenport as a research-entrepreneur in the eyes of Rosenberg. It also demonstrates Davenport's ability to fill the philosopher-scientist role of educational innovator.

Overall, the writings and successes of Davenport show that he possessed skills which were useful in his effort to craft public opinion regarding agricultural education and also in his personal work of building up the College of Agriculture at the University of Illinois. The tangible results at the University of Illinois reveal the success, and it can be assumed that his educational philosophy and deep understanding of the past and present situation of the land-grant movement helped him steer the land-grant movement into its ultimate prosperity in the 20th century.

The Importance of Philosopher-Scientists

As seen in the three above examples of philosopher-scientists from the turn of the 20th century, the unique characteristics they display helped in the advancement of scientific research in the United States. Their broad knowledge base and diverse skill set helped them in this pursuit and allowed for their ultimate successes. However, the above three examples also help reveal three specific roles that philosopher-scientists often took on during their career. Namely, in the case of Wilbur Atwater, the philosopher-scientist is seen as a political activist, seeking to obtain funding to support their research interests which they believed were of the utmost importance for society. In the case of Ellen Richards, the philosopher-scientist is seen as a public servant. This role reveals the desire of these scientists to see their work directly benefit the general population, often with specific emphasis on helping the poor and working classes. And finally, in the case of Eugene Davenport, the philosopher-scientist is seen as an educational innovator, heavily involved in advocating for industrial and agricultural education, again with a heavy emphasis on providing education for the industrial classes.

It is certainly true that each of the above three scientists acted in all three of these roles in different contexts or at different points in their career, and that is exactly the point. Philosopher-scientists are characterized by their ability to utilize their broad knowledge base to fill a number of differing roles. However, these three scientists were chosen, for the sake of demonstration, to highlight each of these roles individually. In the following chapter, the pattern set up using Atwater, Richards, and Davenport will be used to analyze the roles which Henry Armsby, another philosopher-scientist, filled during his time working with the respiration calorimeter at the Pennsylvania State College.

CHAPTER 3

Henry Prentiss Armsby as Philosopher-Scientist

The examples of Wilbur Atwater, Ellen Swallow Richards, and Eugene Davenport were demonstrated in the previous chapter to exemplify three specific roles often played by philosopher-scientists of the land-grant movement. Their mission of advocating for the creation of federally funded universities aimed at benefitting the industrial and working classes through education and research led philosopher-scientists to act as political players, public servants, and educational innovators. In this chapter, this discussion will be carried forward and the above framework will be used to analyze Henry Prentiss Armsby as a philosopher-scientist. Though a considerable number of Armsby's writings hint at his philosopher-scientist characterization, three specific writings exemplify that distinction. These writings include two articles published in *Science* – one written in 1920 entitled "The Organization of Research" and the other written in 1906 entitled "The Promotion of Agricultural Science" – and an address to the American Society of Animal Nutrition delivered in 1909 entitled "The Food Supply of the Future." Each of these provides insight into specific aspects of Armsby's personality, but taken together they also offer a cohesive and more complete picture of Armsby as philosopher-scientist. Therefore, following an individual treatment of each of these three writings, the three sources will be taken together and compared with other writings of Armsby to describe his philosopher-scientist characteristics. The individual treatments of the sources demonstrate the broad knowledge and vision Armsby possessed as a philosopher-scientist, but the synthesis of the sources reveals the nature of how Armsby filled the three roles of philosopher-scientists mentioned above. Finally, Armsby will then be compared to Eugene Davenport, Ellen Richards, and Wilbur Atwater in order to uncover ways in which Armsby was unique in comparison to these peers.

The most influential and characteristic aspect of Armsby's personality was his fixation on the primacy of pure science over practical science. While many of his contemporaries – including, to some extent, the three mentioned in the previous chapter – viewed practical scientific work as the best way to use science to help the public and gain legitimacy, Armsby believed that this focus could be dangerous to the overall scientific endeavor. Within his writings, Armsby always made clear that the concerns of pure science were addressed. The three sources highlighted in this chapter demonstrate this trait. When discussing organization, he cautioned against the loss of individuality that he saw as accompanying the growing influence of governmental agencies in research, as he believed independence to be central to the pursuit of pure science. When discussing the promotion of science to broader, non-scientific audiences, he argued that scientists ought to advocate for pure scientific research. Finally, when discussing the revolutionary changes he wished to see in agricultural research and education, he maintained that the new style of research should be based in pure science and that education should be grounded in that purely scientific work. As demonstrated in the sources discussed below, this continual push for the protection and enhancement of pure science defined the way in which Armsby fulfilled the roles of a philosopher-scientist, and this distinguished him from the three philosopher-scientists mentioned in the previous chapter.

"The Organization of Research" (1920): Balancing Individualism and Cooperation

Originally an address delivered by Armsby in 1919 to the American Association for the Advancement of Science, of which he was the vice-president, "The Age of Organization" was published in *Science* in January 1920. Armsby opened this address by jumping straight to the point, declaring, "This is an age of organization." He argued that the past few decades had been characterized by many industries "pass[ing] in large degree from the individual to the corporate form," with the notable exception of agriculture. He further argued that scientific research is not an institution which is separate and isolated from the tides of societal movements. Rather, he acknowledged that "science is a product of human activity," and therefore must "necessarily be influenced by the spirit of the time." He then pointed to the example of scientists working together to solve the practical problems associated with the entry of the United States into World War I as a clear example of scientists using organization to great success.[171] Much of the research associated with the United States entering World War I was directed by governmental agencies wishing to organize research across the nation. Therefore, integral to Armsby's discussion here was the understanding that cooperation and organization often entailed the involvement of governmental agencies in the work of scientists. Seen to clearly understand this, Armsby had demonstrated himself to be someone who possessed clearly articulated understandings of the influence which society and government have on scientific work.

Following this opening, Armsby posed the two questions he sought to answer with his present discussion. First, would it be justified – and appropriate – for science to move in the direction of organization? And second, would that "enable [research] to render more efficient public service"?[172] This framing of questions offers two important insights. First, we see that Armsby was interested in the idea of efficiency and of science being an avenue towards increasing efficiency. Second, Armsby stated that public service is a key outcome of scientific work, and that when changes are made in the methods of doing science, one ought to always have in mind the impact of the changes on the continuation and improvement of that public

[171] Henry Prentiss Armsby, "The Organization of Research," *Science* 51, no. 1306 (1920): 33, *JSTOR*, Online (accessed on 13 December 2017).
[172] Ibid., 33.

service dimension. These are both key characteristics of philosopher-scientists – as discussed in the previous chapter – and Armsby also clearly prioritized these ideas.

Having fully introduced his topic, Armsby then began the meat of his analysis, beginning with an overview of the history of science, specifically focusing on the balance between individual work and mutual cooperation as pursued by various scientists at different times. He explained that early in the history of science, research was done on "an almost purely individualistic basis," because there was no public support for scientific research. In fact, there was often an indifference towards science. However, as people began to realize that these scientific "dreamers" actually had practical benefits to offer the public, "the scientist came to be recognized as a useful member of society." This trend ultimately culminated, according to Armsby, in the acceptance of the "economic and commercial value" of scientific research. Science then soon came to be seen as a "public function" which ought to be sufficiently funded. Armsby mentioned that many scientific fields began receiving private funding, but he pointed out that agricultural science came to be supported "notably by governmental action." After then providing a brief history of the land-grant movement which culminated in that governmental support of agricultural science, Armsby moved into a discussion of the effects of this historical trend from private work to public sponsorship.[173]

The expansion seen in agricultural research after the beginnings of governmental support was described by Armsby as taking place on "an unprecedented scale." Realizing the success of that expansion, however, Armsby also worried about unintended effects of the success. He wondered whether "the real nature of the end aimed at was sometimes lost sight of in the consideration of the means by which it was to be reached." In other words, Armsby worried that

[173] Armsby, "The Organization of Research," 33-34.

amidst the period of seeking and receiving public support for scientific research, the very nature of what that research sought to attain was obscured.[174] The substance of that nature will be discussed in a bit, but for the present discussion Armsby's second pondering is more critical.

He argued that "it is scarcely to be wondered at that…the proper freedom of research should have been in some degree menaced [amidst the aforementioned changes], on the one hand by bureaucratic administration and the other by the pressure for immediately useful results."[175] These two threats to the freedom of research become the core of Armsby's discussion on the merits of organization in scientific research. The first threat, bureaucratic administration, reveals Armsby's fear that too much influence from large chiefly governmental agencies would limit the freedom of individual researchers to pursue research questions which seem most promising or beneficial in the eyes of the researcher. He obviously believed governmental support was necessary for the funding of research, but he also feared that the bureaucracy of governmental agencies would limit the freedom of individual scientists. The second threat, "the pressure for immediately useful results," reveals that Armsby, though acknowledging science's role in benefitting the public, feared that scientific work focused solely on solving immediate, practical problems would hinder research into the fundamental principles which have longer lasting importance.

These worries reveal that Armsby held a surprisingly nuanced position in relation to this issue of organization. For example, after listing these worries, he mentioned that in recent years there had been a "wholesome reaction" of "stress[ing] the fundamental significance of the initiative and independence of the individual investigator." However, he immediately follows that by arguing that "by the time the United States entered the war…there was perhaps a

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[174] Armsby, "The Organization of Research," 34.
[175] Ibid., 34.

tendency to excessive individualism and a certain lack of coordination and cooperation in agricultural research."[176] Rather than simply arguing that the best path forward is either wholesale acceptance or rejection of organization, Armsby had set the stage for a delicately balanced analysis of the two options at hand. He obviously held deep concerns over the limiting of individual autonomy, but in the very next paragraph he states the too much autonomy is also undesirable. Adhering to a more definitive or absolute argument would clearly be an easy path towards advocating for specific action, but never one to seek a simple answer for the sake of ease, Armsby dove into a much deeper analysis of the issue. This proclivity to embrace nuance in a discussion such as this is noteworthy, and it further demonstrates Armsby's nature as a philosopher-scientist.

Contained within that nuanced position are two balances which formed the core of Armsby's discussion. These are the balance between individualism and organization, and the balance between practical science and pure science. The balance between practical and pure science will be developed in greater depth later, as it plays an even more central role in another of Armsby's writings, but because Armsby related his discussion on individualism and organization to the dichotomy of practical and pure science, a brief explanation of that balance is merited.

In a 1906 article entitled "The Promotion of Agricultural Science," Armsby provided perhaps the best definition of the distinction between practical and pure science stating, "Investigation is [purely] scientific, as distinguished from practical, when it is undertaken with the prime object of enlarging our knowledge of principles and without immediate reference to

[176] Armsby, "The Organization of Research," 34.

practical application."[177] Throughout his writings, Armsby discussed this separation of scientific work into the categories of "practical," which sought to solve immediate and practical issues, and "pure," which sought to uncover underlying, fundamental scientific principles which would help advance general scientific understandings of a given issue. Put more succinctly, Armsby described pure science as having the incentive of "desiring to know more" while practical science has "the ambition to do more."[178] Armsby saw value in both of these categories of scientific work, but he always maintained that the fundamental nature of pure science made it much more important than practical science. As such, the positions Armsby took in this address were based in his desire for heightened pure scientific work.

Regarding the balance of individualism and organization, the distinction is more inherently apparent. The viewpoint of individualism in science is characterized by Armsby's appeals to the ideals of "freedom of research" and the "independence of the individual investigator."[179] On the other hand, organization is most readily defined as a state in which cooperation is central. This can be seen in Armsby's equating "excessive individualism" with a "lack of coordination and cooperation."[180] Following his explanation of the worries mentioned earlier, Armsby proceeded to outline the benefits of organized and cooperative research. He quoted various experts who had advocated for a move toward organization in science, one of whom explained that "isolated, more or less competitive investigations have resulted in a certain amount of progress; but it has been very slow compared with what cooperation would have

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[177] Henry Prentiss Armsby, "The Promotion of Agricultural Science," *Science* 24, no. 622 (1906): 674, *JSTOR*, Online (accessed on 13 December 2017). This source, and the distinction between pure and practical science, is discussed in greater detail within the section devoted to this particular article.
[178] Armsby, "The Promotion of Agricultural Science," 674.
[179] Armsby, "The Organization of Research," 34. The obvious connotations of "freedom" and "independence" in this characterization certainly makes one wonder about the influence of the Age of Revolutions of the 18th and 19th centuries on the understandings of individualism in science. Though this would certainly be a fruitful and interesting line of investigation, that topic is not handled in the present analysis.
[180] Ibid., 34.

secured." Armsby then listed many "convincing examples of success in scientific cooperation" to further strengthen the argument, including "the striking wartime achievements in the applications of chemistry, physics, and engineering."[181] But again, hesitant to advocate definitively in one direction, Armsby cautioned his readers who may be too readily agreeing,

> But not withstanding all these emphatic dicta, may it not be well to call a moment's halt to consider whither this tide is carrying us and whether it really 'leads on to fortune.' May there not be a certain danger of overlooking the significance of the individual? We must beware of being stampeded by the brilliant successes of the war time into an undue exaltation of the virtues of cooperation and organization.[182]

He was not denying the value of those "virtues," and emphasized that they are valuable, but he also believed it necessary that the importance of individualism be emphasized as well. He argued, "It is just as true to-day as it ever was that the permanent and significant advances of science depend…on the initiative and originality of individuals. Nothing can alter this fundamental fact."[183] This description of the obvious successes of organization and the inherent importance of individualism then led Armsby into the explanation of his primary argument.

In an effort to consider the benefits of each side of this debate, Armsby settled on the fact that different kinds of scientific work may be more readily applicable to individualism or organization. To demonstrate this, he argued that "the problems of war-time cooperation were largely the problems of practice and it is these practical problems which seem to offer the greatest opportunity for cooperation." On the other hand, for the scientist pursuing the study of the most fundamental of problems, performing the purest of pure science, "the best thing that can be done…is to supply him with the necessary equipment and facilities and then let him alone. Committees and cooperators are in danger of being hindrances rather than helps."[184] In essence,

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[181] Armsby, "The Organization of Research," 35.
[182] Ibid., 35.
[183] Ibid., 35.
[184] Ibid., 35.

Armsby argued that more practical work lent itself well to more organization while more pure work lent itself to more individualism.

He then softened this rather sharp divide by pointing out that very few scientists truly fall into the category of doing completely pure research, and that most “ordinary researchers” fall somewhere in the middle of the spectrum between practical and pure research. Therefore, in most cases, a compromise between individualism and organization must be struck. Armsby acknowledged that on the one hand, ordinary investigators “can profit most largely by mutual association,” but that on the other hand, those researchers are the most endangered by the suppression of “the initiative and inspiration of the individual.” He believed that if the proper balance could be struck, the downsides of each option could be mitigated, while the benefits of each could be enhanced. He believed this proper balance could provide scientists with “the inspiration and stimulus to initiative which comes from close contact with their fellow workers.”[185] Again, it is seen that though Armsby valued the role of organization, often characterized by governmental agencies, he also worried that too much organization or governmental involvement would limit the potential of individual scientific work. In his own words, he summed up this position as follows,

> In brief the teaching of our war experiences, as I see it, is that our rate of future scientific progress will depend, not exclusively upon cooperation on the one hand nor upon individualism on the other but upon a wise combination and adjustment of the two in varying proportions according to the nature of the problem attacked and the abilities of the investigators concerned.[186]

From this summation, it is clear that Armsby’s ability to analyze both sides of the argument allowed him to develop a position which offered a better chance at success than would have been

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[185] Armsby, “The Organization of Research,” 36.

[186] Ibid., 36. An additional, more succinct and more poetic summation can be found on page 37 of the same article in which Armsby says, “Individualism and cooperation must not be antagonists but yokefellows in the chariot of science.”

possible had he allowed himself to be swept away by the tide of one choice over the other. He was able to find a solution which allowed for the necessary role of organizational involvement without sacrificing the important influence of individual research interests.

Armsby concluded this address with a discussion of the means by which "cooperative effort, where desirable, [could] be most efficiently organized." He listed three specific criteria which any cooperative organization must fulfill – these included that the work of the organization "be directed to really significant and fundamental research problems," that sound methods be employed to avoid "empirical experiments leading nowhere," and that the organization "secure the stimulus to zeal and persistence which comes from association in a common cause."[187] In addition, because the organization will be – and must be – made up of "self-directed workers," Armsby argued, "any organization of them must be democratic," and that the workers "are all partners in the enterprise and sharers in its profits." Therefore, according to Armsby, "Effective cooperation cannot be imposed from above by administrative authority but can only come by free democratic action of investigators themselves." Armsby believed this could best be achieved by an organization which was characterized by "the tie of common interest and a common purpose."[188] An organization united by a common purpose would be inherently democratic and would by its nature allow for the necessary independence of individual researchers from governmental overreach while also providing the benefits of a cooperative organization. In the following source, Armsby discussed a specific example of one such organization.

[187] Following the first item of this list, Armsby gives his reasoning for the work needing to be directed to significant and fundamental problems saying, "The issues of civilization are too vast for us to lapse into dilettanteism," as seen in, "The Organization of Research," 36.
[188] Ibid., 37.

"The Promotion of Agricultural Science" (1906): Pure vs. Practical Science

In November 1906, almost 15 years before the publishing of "The Organization of Research," another article written by Armsby was published in *Science.* Though Armsby sought to discuss a separate topic in this earlier article, many of the same themes from his 1920 article are present. For example, the opening of "The Promotion of Agricultural Science" began with a brief history of agricultural science advancement. It mentioned that The Society for the Promotion of Agricultural Science was founded in 1880 and that at the time of the organization's founding, "workers in agricultural science in the United States were few and scattered," hence the need for the organization. However, as has been mentioned numerous times above, the intervening quarter of a century, in the words of Armsby, "witnessed a phenomenal development of agricultural education and investigation," and the time had come where "the young student of the present day can hardly realize the conditions which existed a generation ago." The number of agricultural experiment stations had grown from six to sixty in that relatively short span of time, and Armsby also pointed out that the "land grant colleges, too, from feeble and more or less destitute 'cow colleges' have acquired an acknowledged and honored position among the institutions for technical education."[189] Having observed all of this "stupendous change," Armsby then pondered whether organizations such as The Society for the Promotion of Agricultural Science were still necessary, asking,

> Are not all these public institutions agencies for scientific investigation in agriculture on a scale and with resources such as to make a private organization superfluous? Is it still necessary to promote agricultural science?[190]

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[189] Armsby, "The Promotion of Agricultural Science," 673-674.
[190] Ibid., 674.

These are the questions Armsby wished to answer in this article, and his answers ultimately reveal his beliefs about the nature and importance of scientific investigation and how outside influences should affect scientific work.

Armsby began his answering of these questions by providing a few helpful definitions. He defined agricultural science as "that body of scientific principles, known or discoverable, which underlies and conditions successful agriculture." He then defined the promotion of agricultural science as being "the support of any measures calculated to give us a deeper and more comprehensive knowledge of these principles."[191] Though these may seem like straightforward and expected definitions of these terms, Armsby's next statements demonstrate their subtler importance. Offering a more succinct definition, Armsby stated, "[the promotion of agricultural science] is equivalent to the promotion of scientific investigation in the field of agriculture." It is here that Armsby offered the definition of pure versus practical science discussed in the previous section. He explained, "Investigation is scientific, as distinguished from practical, when it is undertaken with the prime object of enlarging our knowledge of principles and without immediate reference to practical application."[192] In other writings, Armsby certainly seems to consider practical science to be considered a part of scientific work – and as such I will continue to refer to the two distinctions as pure science and practical science – but the fact that Armsby seems here to separate practical investigation from scientific investigation is worth noting. Based on the distinction Armsby made here, it appears that every subsequent reference to "research" and "scientific investigation" within this article refers specifically to pure science over practical science, and will therefore be treated as such.

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[191] Armsby, "The Promotion of Agricultural Science," 674.
[192] Ibid., 674.

With an understanding of that distinction in mind, a reading of this article reveals Armsby's beliefs about the importance of pure scientific work. He argued that investigation of that sort has "fundamental importance" and said that "[r]esearch forms the ultimate basis of all agricultural as of all other progress."[193] He then transitioned into a discussion of the challenges facing that sort of investigation, beginning with a quote from another *Science* article written by a different researcher. He pointed out that in the last sentence of that quote, one could find "the serious danger that threatens agricultural research in the United States." The sentence being referred to read,

> The experiment stations, even, do not disobey the general rule, for the demand for immediate results of economic value is such that the workers are almost obliged, in the majority of cases, to desist from work a broad and fundamental character, while most of them, of course, have to do a large amount of teaching.[194]

Though the challenges associated with teaching duties were important to Armsby, more pertinent to the present discussion is the challenge which comes from the tendency towards seeking "immediate results of economic value," or in other words, the tendency towards pursuing practical science over pure science. Armsby went on to acknowledge the "wonderful record of progress on the material and practical side [of scientific work]" which had been seen over the prior quarter century. He emphasized that such progress had been necessary during the struggle to gain public support for scientific work by demonstrating the importance and utility of that work.[195] But he also acknowledged that

> while the popular work of the stations and colleges is of vast importance and benefit, we must not forget that it all rests on the truths of science, and that unless science makes progress the popular work will soon be marking time.[196]

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[193] Armsby, "The Promotion of Agricultural Science," 674.
[194] Ibid., 675. Though Armsby certainly had qualms about the burden of teaching responsibilities on researchers, the later part of the article suggests that concern is not primary here.
[195] Ibid., 676.
[196] Ibid., 677.

Here, Armsby's beliefs regarding the relationship between pure and practical science can most clearly be seen. Though Armsby believed practical science to have importance, he also believed that pure science uncovers the underlying principles which lead to success in practical science. Therefore, practical science is dependent on pure science. It therefore appears Armsby valued pure science over practical science, if anything, because of pure science's fundamental nature and the ability of pure science to inform all other kinds of research.

Because Armsby believed pure scientific work to be so vital to the success of scientific research more generally, he also believed that viewpoint ought to be promoted by scientists. It was this belief which led Armsby to argue that the challenges facing experiment stations and agricultural colleges call for "strong men with an abiding faith in the fundamental and ultimate importance of scientific research." This need for scientists with faith in pure science led Armsby to make the main point of his article, "There is still need for the promotion of agricultural science."[197] In support of that argument, Armsby cited a current situation facing the experiment stations. He explained that in 1906, the passage by Congress of the Adams Act "doubled the United States appropriation to experiment stations." Armsby believed the passage of that Act offered "great opportunity" to experiment stations, but also believed it would "prove also to be a day of judgement for the stations."[198] He outlined the choice they now faced,

> The stations stand at the parting of the ways. Will they simply add demonstration to demonstration, propaganda to propaganda, or will they grasp the opportunity to dedicate this new fund sacredly and irrevocably to original scientific research, broadly conceived and liberally executed.[199]

Armsby believed that choice would not be an easy one to make. He went as far as admitting that he would be considered an "idealist" for his belief that unhindered pure scientific research could

[197] Armsby, "The Promotion of Agricultural Science," 678.
[198] Ibid., 677.
[199] Ibid., 677.

be pursued. But he also argued that if The Society for the Promotion of Agricultural Science advocated for the promotion of pure science, then "real progress" could be made.[200]

Within the concluding paragraph of this article, Armsby said he was "well aware that these suggestions [outlined above] may appear revolutionary." He admitted that he had "little faith in revolutions as a means of progress," but acknowledged that "they have occasionally been unavoidable."[201] Armsby certainly believed a revolution to be necessary in this case. Seeing the immense desire among many scientists to pursue the immediate solutions of practical science, he consistently called for a reversal of such beliefs. He knew that people would be resistant to such a change, but in the manner of a revolutionary leader, he frequently used his writings to argue how his views would ultimately help society more than the current state of affairs. In the address discussed below, that sentiment is made even clearer.

"The Food Supply of the Future" (1909): The Need for a Revolution in Research

In 1909, as President of The American Society of Animal Nutrition, Armsby delivered an address entitled "The Food Supply of the Future" at the annual meeting of the society. In the opening of this address, Armsby immediately indicated that his message would be important by warning his audience that a food supply shortage was looming for the United States. He supported this claim by quoting from many experts in various fields, including Eugene Davenport, who is quoted as remarking, "There is to be, in the very near future, a struggle for land and the food it will produce such as the world has never beheld. He who knows where and how to look can see it coming."[202] The experts Armsby quoted obviously knew where to look, as

[200] Armsby, "The Promotion of Agricultural Science," 678.
[201] Ibid., 681.
[202] Henry Prentiss Armsby, "The Food Supply of the Future," Proceedings of The American Society of Animal Nutrition (1909), 4, found in Collected Papers of the Animal Nutrition Institute, Eberly Family Special Collections Library, The Pennsylvania State University, University Park, PA.

each one discussed the dangers associated with an increase of population which is not accompanied by an increase in food supply. One especially dramatic prediction was given by J. L. Snyder, the President of the Association of American Agricultural Colleges and Experiment Stations, in which he said that if people were not adequately and equally fed, they "would separate into classes and become estranged from each other. The power usually goes with wealth, but the men compelled to live on cheap food would soon get into the same political party and perhaps gain control of the national government." Then Snyder quotes from Lord Macauley, warning, "Either civilization or liberty will perish."[203] Like the experts he quoted, Armsby clearly also saw the problem of food shortage coming, made more evident by his concluding this introductory section remarking that, "it would be foolish in the extreme to close our eyes to the fact that the intensity of [the food supply problem] will exceed anything we have yet known."[204] The address following this introduction can then be viewed as Armsby's way of opening the society's eyes to the problem he has just outlined.

In the next few sections, Armsby gave a broad overview of the scientific principles behind the solution he saw for the problem presented above. The specifics of that discussion will be analyzed in the next chapter, but the main argument he made is that the "continuance of life on earth" and, more specifically, the "density of population which a country can support," is dependent on scientists uncovering principles which will allow for the creation of "efficient [animal] rations" which will "save the largest possible percentage of the energy which they contain."[205] His reasoning for that need, though heavily based in scientific arguments, is full of

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[203] Armsby, "The Food Supply of the Future," 5-6.
[204] Ibid., 6.
[205] Ibid., 6-7.

references to ideas of efficiency, profit, and reducing waste. This is especially prevalent in a vision of the future he provided, in which he said,

> The feeder of the future will utilize by-product feeds to an extent as yet unrealized. He will pass in review the crude products of the farm, and all the hundred and one wastes of manufacturing operations to see if perchance they still contain energy which he can extract. Like the miner, he will be ready to work low grade ore provided there is a sufficient margin of profit.[206]

Much like the philosopher-scientists discussed in the previous chapter, Armsby's scientific arguments are filled with the industrial ideals which permeated the society of his time.

Armsby then changed the thrust of his address. Shifting away from his discussion of the problems he saw and the broad solutions he proposed, he began describing more specific ways in which those solutions may be implemented. He set the tone of this portion with his opening statements,

> The questions which we have been considering are very broad ones. They signify nothing less than a revolution, no less real because gradual, in the methods of agriculture as a whole and of the production of animal foods in particular and the conditions which we must expect in the future will call for a much higher degree of skill in adapting means to ends than has been necessary in the past.[207]

Armsby clearly saw the great changes he was calling for, but he also believed those changes to be attainable, and he spent the remainder of this address outlining how they could be attained, beginning with the question, "What, then should be the attitude of the institutions for agricultural teaching and research toward the problem of the future food supply?"[208] In other words, how should the land-grant institutions work toward solving these dire problems?

Armsby provided three specific avenues on which to focus. Two of these reiterate themes developed above – namely he called for investigation which is focused on uncovering "the

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[206] Armsby, "The Food Supply of the Future," 8.
[207] Ibid., 9.
[208] Ibid., 9.

scientific principles of animal nutrition," and for a "co-ordination of effort and of spirit combined with the largest possible scope for individual initiative."[209] Therefore, Armsby is again seen to advocate for pure scientific research which is characterized by organization that also allows for individuality. The yet unmentioned avenue of focus is Armsby's view on how education ought to fit within this radically new system. He argued that the land-grant institutions, "while still teaching the approved practices of the present must as their chief aim seek to equip students with a sound knowledge of underlying facts and laws and thus prepare them to meet the changing conditions of the future."[210] Ending this description of his three focuses, Armsby once again highlighted the importance of taking these steps, arguing, "It is not alone our food supply but our democracy which is at stake."[211]

Armsby ended this address with a short conclusion full of language which hints at the revolutionary nature of the solutions he had presented. He believed that the current nature and direction of research would not solve the issues of the food supply. Rather, he believed a unity of purpose should be taken up and applied to the pursuit of pure science over practical science. Calling for the efforts of the national government to "be in harmony" with the investigations of individual agencies and arguing that "all the available forces should unite in the study of these important questions" without any "local jealousies [being] allowed to stand in the way," Armsby employed many of the same strategies employed by other figures who believed a radical change to be necessary at a given time. Continuing in his emulation of a revolutionary leader, Armsby focused on The American Society of Animal Nutrition and claimed, "If I understand the spirit and temper of [the society's] members, they desire to make the society something more than a

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[209] Armsby, "The Food Supply of the Future," 10-12.
[210] Ibid., 9.
[211] Ibid., 12.

pleasant club or a gathering for the reading of papers." He ended his speech with the following explanation his desires: "It is my hope…that [the society] may become an active agency in forwarding the solution of some of the problems which I have attempted to indicate in this address."[212] He no longer wished this society to be a meeting of scientists for the sake of simply presenting research. Rather, he wished to see the society take its proper role at the head of a new revolutionary endeavor aimed at heightening the public's approval of pure science. This, Armsby believed, would be the only way to solve the problems of the nation's food supply.

The Philosopher-Scientist Roles of Henry Prentiss Armsby

Armsby has been shown to clearly possess the broadness of interest and vision which is characteristic of philosopher-scientists. His writings reveal him to have had deep understandings of the history and philosophy of science and these understandings led him to take remarkably nuanced positions on many issues related to science's role in society. This broadness also impacted the way he filled the various roles of philosopher-scientists which were discussed in the previous chapter. An analysis of Armsby's writings, taken together, reveals that he fit into the roles of public servant, educational innovator, and political actor, just as many of his contemporaries did. However, Armsby's beliefs regarding the primacy of pure scientific research impacted the extent to which he pursued each of these roles, and therefore distinguished him from other scientists of his era. Rather than wholeheartedly pursuing one specific role at the expense of all other endeavors, Armsby was characteristically cautious that his pursuit of a given role did not minimize the status of the pure science he believed to be of primary importance.

As demonstrated in his address, "The Food Supply of the Future," the primary motivation behind Armsby's nutrition research was in solving issues he saw with the food supply of

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[212] Armsby, "The Food Supply of the Future," 13.

growing populations. All of his scientific work dealt, in one way or another, with this issue. He believed that agricultural scientists should research the underlying principles of nutrition, specifically related to the conversion of the energy contained in feedstocks into the meat or dairy production of livestock. Seeing much inefficiency and waste in the current methods of meat production, Armsby believed scientists could uncover principles which would allow farmers to feed the most efficient rations to their animals. He believed this would ultimately lead to humans acquiring the most amount of energy from their food through eating the meat of efficiently fed animals.

Though this belief is heavily influenced by his theories regarding animal nutrition, Armsby also believed this work fulfilled the natural role of scientists helping the public. In his 1909 address, after describing his vision of the future in which the "feeder of the future" would utilize feedstocks to their highest and most efficient capacity, Armsby said that "to aid in rendering this possible is to render service to mankind."[213] In a 1911 article published in *The Popular Science Monthly*, he made a similar argument. Though the results of his research may most directly impact the practices of farmers, the problem being studied was, according to Armsby, "one which vitally concerns the welfare not of the farmer alone but of the whole people."[214] Further, Armsby believed that not solving the problem of the food supply would have drastic consequences. As he explained, "It is not alone our food supply but our democracy which

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[213] Armsby, "The Food Supply of the Future," 8.

[214] Henry Prentiss Armsby, "The Conservation of the Food Supply," *The Popular Science Monthly*, November 1911, 501, found in Collected Papers of the Animal Nutrition Institute, Eberly Family Special Collections Library, The Pennsylvania State University, University Park, PA. This source, which echoes many of the themes of "The Food Supply of the Future," is quite possibly a written version of his spoken address tailored for publishing in this magazine, which likely would be read more widely than his address. The motivations for this may be very similar to Atwater's decision to publish a series of articles in the *Century* magazine.

is at stake."[215] Clearly, Armsby saw his plan of nutrition experimentation and research as a work of public service, because the issue at hand was intrinsically linked to the welfare of humanity.

In addition, Armsby invariably made sure that the issue of public service was prominent in his discussions of various issues. In "The Promotion of Agricultural Science," for example, he emphasized that in order for scientific work to receive the support of the public, "the public must come to understand better…[research's] importance from the point of view of the general welfare."[216] If there were no public benefits of research, Armsby would have no need to make this point, so Armsby clearly believed there to be a fundamental way that science benefits the public. When stating the two issues he wished to analyze in "The Organization of Research," he says he planned "to inquire…into the extent to which [organization] is justified," but also into "the probability that a more complete organization of research will enable it to render more efficient public service."[217] Armsby revealed in this quote that public service was at the forefront of his mind and that he did not wish to pursue an option which did not give proper attention to the help science should provide to the public.

Based on his adherence to the importance of public service, it is somewhat surprising that Armsby also consistently cautions against the single-minded pursuit of practical science, which at its heart seeks to solve problems facing society. How could he on one hand say that scientific work ought to help the public, but on the other hand argue that focusing on solving the public's problems "threatens to be [the experiment stations'] permanent undoing"?[218] A resolution to this apparent contradiction was provided by Armsby when he said, "while the popular work of the stations and colleges is of vast importance and benefit, we must not forget that it all rests on the

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215 Armsby, "The Food Supply of the Future," 12.
216 Armsby, "The Promotion of Agricultural Science," 678.
217 Armsby, "The Organization of Research," 33.
218 Armsby, "The Promotion of Agricultural Science," 676.

truths of science."[219] Because he believed practical science rested on the principles of pure science, he also believed that the best way to enhance practical science – which directly serves the public – is to enhance the pure science which underlays it. Armsby also believed that practical scientists could help demonstrate the utility of pure science, as demonstrated in this quote from a 1911 address entitled "Some Unsolved Problems,"

> I have said that the investigator needs recognition by the public if research is to flourish. From whom and through whom should this recognition come in the first instance if not from his associates [who pursue practical science]? Should he not be encouraged in his work and at the same time helped to make it of more practical significance by the appreciation and intelligent criticism of his colleagues?[220]

It seems from these rhetorical questions that Armsby saw value in both pure and practical science. Pure science uncovers principles, but practical science applies the principles of pure science for the benefit of the public. Even with this balance, it certainly seems that Armsby favored pure science over practical. In many ways, Armsby saw practical science as simply the arm of scientific research which applied scientific principles in ways to serve the public.

Taking all of this into account, Armsby's role as a public servant can be analyzed. He clearly believed public service to be a crucial responsibility of scientists. He often discussed that responsibility in terms of scientists helping the public in an effort to convince people of the need for support. But there are also plenty of instances – "The Food Supply of the Future" and "The Conservation of the Food Supply," as examples – in which Armsby discussed scientific work primarily in terms of how it would help society. These instances demonstrate that Armsby did not simply appeal to public service in an attempt to receive support for his work. Rather, Armsby saw his role of public servant as being critical to his being a scientist.

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[219] Armsby, "The Promotion of Agricultural Science," 677.
[220] Henry Prentiss Armsby, "Some Unsolved Problems," Proceedings of The American Society of Animal Nutrition (1911), 7, found in Collected Papers of the Animal Nutrition Institute, Eberly Family Special Collections Library, The Pennsylvania State University, University Park, PA.

Armsby is also seen to fill the role of educational innovator. Within that role, he advocated for the education of two groups. The first of these was the general public. As mentioned above, Armsby believed that the public ought to be educated about the importance of research and how it affects the "general welfare."[221] He believed all scientists should also desire that, asking, "Should not individuals and societies which stand for the promotion of science…take greater heed to the formation of an enlightened public opinion?"[222]

Farmers formed the core of the second group that Armsby wished to educate. He believed farmers played a vitally important role in the process of energy conversion from the sun to plants to animals and ultimately to humans. He even went as far as contending that "the density of population which a country can support…is practically limited by the amount of solar energy which the farmer can recover in food products."[223] The farmer obviously therefore played an important role in Armsby's solution for solving the food supply problem. This importance required, according to Armsby, "that the farmer is taught how by means of tillage, fertilization, seed selection, crop rotation, and all the arts of good farming to accumulate as much as possible of the solar energy in his yearly crops."[224]

Armsby also maintained in both of these cases that the education should be based on pure scientific principles. Regarding the general public, he believed they should be educated to have "a greater appreciation of the need for scientific investigation into the underlying principles of agriculture."[225] Regarding farmers, he said that once the research had been done, scientists would "possess the scientific basis for a rational system of conserving to the utmost for man's use the

[221] Armsby, "The Promotion of Agricultural Science," 678.
[222] Ibid., 679.
[223] Armsby, "The Conservation of the Food Supply," 496.
[224] Ibid., 496.
[225] Armsby, "The Promotion of Agricultural Science," 679.

energy which the studies of [various scientists] have taught the farmer how to accumulate in his crops."[226] Therefore, it can be seen that Armsby believed his plans for solving the food supply problem required a specific style of education based on pure science.

Being a leader within the land-grant movement, Armsby also applied these principles to how he believed the education at land-grant institutions should be structured. He certainly still placed a high emphasis on the teaching of pure science, as will be seen shortly, but it is also worth noting a passage in which he advocated for a decent level of practical education as well. Take for example, an instance in which he described a problem he saw with the current system,

> We must recognize…that there has been…a gap in our agricultural institutions taken as a whole between the student of the science of nutrition and the expert in the art of feeding…The scientific man has been too exclusively scientific and the practical man too exclusively practical and the result has been unfortunate for both.[227]

He went on to explain that the practical and the pure ought to be in close contact within education. However, this does not detract from his belief that pure science should be the focus. Many land-grant institutions at the time were focused primarily, if not overwhelmingly, on practical education. Therefore, for Armsby to say that pure science ought to also be included revealed the importance he placed on having pure science be a part of education. Elsewhere he provided another picture of his vision for the land-grant institutions, explaining "our colleges while still teaching the approved practices of the present must as their chief aim seek to equip their students with a sound knowledge of underlying facts and laws."[228] Here it is again seen that Armsby saw value in having practical and pure science within education, but he maintained that pure science should be primary. In yet another instance, Armsby argued, "Research forms the ultimate basis of all agricultural as of all other progress, whether in the school, the college, the

[226] Armsby, "The Conservation of the Food Supply," 501.
[227] Armsby, "Some Unsolved Problems," 7.
[228] Armsby, "The Food Supply of the Future," 9.

correspondence course or on the farm."[229] All of these examples reveal that Armsby consistently advocated for education – whether for the public, farmers, or university students – which was based primarily in pure scientific principles. Therefore, in the role of educational innovator, Armsby's beliefs regarding pure science shaped the way in which he acted as a philosopher-scientist.

As a political actor, Armsby believed that the government should fund scientific research, and as such continually advocated for such funding to be maintained if not increased. This is seen especially well in "The Promotion of Agricultural Science." In that address he explained that the agricultural colleges and experiment stations "had to demonstrate their right to be supported from the public purse."[230] Armsby's use of the word *right* in this statement seems very intentional and reveals his belief that government support of science is something natural and something which should be protected. Also, when describing the Adams Act of 1906 which doubled the amount of money given to experiment stations from the federal government, Armsby called the passage of this act "a notable forward step," again revealing his belief that such funding is an expected and necessary thing.[231] Armsby was certainly aware of the ultimate source of this government funding, as he explained,

> Few of us are so fortunate as to be able ourselves to defray the expenses of our own investigations. Most of us are dependent for the necessary funds upon the approval of boards of trustees or other superior officers, or, since these usually represent the public, we may say that we are dependent upon popular approval or at least tolerance.[232]

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[229] Armsby, "The Promotion of Agricultural Science," 674.
[230] Ibid., 675.
[231] Ibid., 677.
[232] Ibid., 678.

These statements all demonstrate that Armsby believed the government ought to support scientific research. But as in his other roles, the extent to which he advocated for this was influenced by his views on the primacy of pure science.

One of the main arguments Armsby made in "The Organization of Research" was that pure science was best fostered by individual work rather than cooperative work. And because he believed pure scientific research should be primary, he was also reticent of any encroachment by overarching agencies into the individualistic work of scientists. For example, he listed "bureaucratic administration" as one threat to "the proper freedom of research."[233] However, he also lists the United States Department of Agriculture and the War Board of the American Society of Phytopathologists, both governmental agencies, as "convincing examples of success in scientific cooperation."[234] Of course, he is speaking of practical science in this case, but regardless of this, obviously Armsby still saw some value to agencies such as these. He even once described the USDA as a "great department." But even in these cases, he warned against too much encroachment by these agencies. In the case of the USDA he said that "its work in [problems of feeding] should be productive as well as protective."[235] He believed that "effective cooperation cannot be imposed from above by administrative authority but can only come by free democratic action of investigators themselves."[236] So for Armsby, even cooperation was dependent on individual actions.

One agency which Armsby believed had done a good job of striking this balance between government involvement and deference to individualism was the National Research Council. Founded in 1916, the Council was created with the goal of "bring[ing] into cooperation existing

[233] Armsby, "The Organization of Research," 34.
[234] Ibid., 35.
[235] Armsby, "The Food Supply of the Future," 12.
[236] Armsby, "The Organization of Research," 37.

governmental, educational, industrial and other research organizations" in order to encourage scientific research into areas which would "promote national security and welfare."[237] As seen in his discussion of the organization of scientific work, Armsby saw some value in cooperation as represented by the National Research Council, and he certainly would have approved of its focus on the promotion of pure science. An article from *Scientific American* revealed the focus of the Council on pure science when it explained,

> Thus for the first time in the history of this country…science, education, industry and the federal government have joined hands in a plan for the promotion of research, as such, without stipulations or preoccupations as to immediate "practical" returns.[238]

Based on this description, Armsby surely would have fully embraced what the National Research Council stood for. He praised any sort of organization which helped in the pursuit and promotion of pure scientific research. This adoration is seen when Armsby called the Council "the most significant and comprehensive achievement in the organization of American research."[239] His praise of the Council revealed his feelings toward it, but also outlined the nature of his ideal means of government supporting research through agencies. Armsby said,

> [The Council's] organization is peculiarly significant because it was effected by the voluntary initiative of the investigators themselves and because, therefore, it is thoroughly democratic in form and has been careful both in its initiation and development to conserve the individuality of the research men.[240]

Based on that description, it is pretty easy to see why Armsby admired the National Research Council so greatly.

However, in May 1917, Armsby felt the ideal nature of the Council was being threatened. A bill had been proposed in the United States Senate which called for the formation of a National

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[237] Rexmond C. Cochrane, "World War I and the Creation of the National Research Council," in *The National Academy of Sciences: The First Hundred Years, 1863-1963,* (Washington, D.C.: National Academy of Sciences, 1978), 209.
[238] Cochrane, "World War I and the Creation of the National Research Council," 213.
[239] Armsby, "The Organization of Research," 38.
[240] Ibid., 38.

Board of Engineering and Industrial Research. Feeling worried by this development, Armsby wrote to Dr. George Hale, the Chairman of the National Research Council, asking whether the Council supported the bill. When Hale responded that the Council had not yet issued an opinion on the bill, Armsby responded, "I venture to hope that this bill, which seems on its face inconsistent with the expressed policies of the Council regarding the importance of individual freedom and initiative in research will not be allowed to become a law without careful consideration by the Council."[241] Armsby clearly believed something about the proposed Board would hamper individualism in research, and therefore hamper the pursuit of pure science. His writing to Hale demonstrated Armsby's willingness to advocate to the government his views on how scientific research ought to be supported. He consistently argued that governmental support was necessary, but not when that support threatened the individualism which cultivated the study of pure science.

Analysis of Armsby's writing plainly demonstrates that he fulfilled the three key roles of philosopher-scientists. As mentioned before, these three roles certainly overlap in many ways – education of people about the public benefits of science demonstrated the need for governmental support of science, as an example which involves all three roles – but there are also many cases in which Armsby can be seen to be filling one role at a given time more than another role. This is also characteristic of a philosopher-scientist, as having an understanding of societal contexts helps in this shifting of focuses.

Compared to the three philosopher-scientists of the previous chapter, however, Armsby was distinctive because of his focus on the sanctity of pure science. In each of the three roles, he was characteristically careful to protect the pursuit of pure science. As a public servant, he

[241] Henry Armsby to George Hale, May 1917, Collected Papers of the Animal Nutrition Institute, Eberly Family Special Collections Library, The Pennsylvania State University, University Park, PA.

acknowledged that practical science most directly benefitted the public but that pure science was ultimately what supported the practical work. He therefore argued against any push toward focusing purely on practical science, even if that push was being done for the sake of helping the public.

Ellen Richards insisted that the importance of scientific work lie primarily in the fact that it can help people immediately. In fact, the immediacy of the effects she foresaw for Euthenics was the core of her argument in favor of "Euthenics" over Eugenics. Armsby consistently argued that a focus on finding immediate results simply detracted from the pursuit of pure science, which he believed would do the most long-lasting good. Therefore, though Armsby, like Ellen Richards, filled the role of public servant, the extent and manner of his pursuing this role was always affected by his attitudes towards the primacy of pure science over practical science.

As an educational innovator, Armsby advocated for a change in educational systems. He insisted that whether the education be directed informally to the public and farmers or more formally to university students the education should be based primarily in the fundamental principles of pure science. Eugene Davenport undoubtedly agreed with Armsby in many ways. In fact, as noted previously, Armsby quoted Davenport in "The Food Supply of the Future," an address at least partially devoted to advocating for a new educational system.

However, though Armsby and Davenport would have both agreed that a new style of education was needed, the exact nature of that education would likely have caused some debate between the two men. Davenport primarily advocated for a system characterized by a democratization of education through opening the institutions to people all classes and by a focus on training in methods of efficiency. Davenport believed vocational training, which was closely related to practical science, should play a major – even if not necessarily primary – role in education. He certainly believed other aspects of education were important, but each aspect was always related back to the idea of efficient applications. Armsby also argued that a wider education was necessary for science to benefit society at its greatest capacity, but he believed pure scientific principles should be the core of that education. Similar to Davenport's fixation on efficiency, Armsby was fixated on pure science. Therefore, though they both called for a revolutionary change in the nature of education, Armsby and Eugene Davenport did not fully agree on the specifics of what that new nature should be.

As a political actor, Armsby advocated for governmental support and funding. But he was also wary of intrusion from bureaucratic agencies which limited the potential for pure scientific research. Wilbur Atwater also consistently called for governmental support of science, but he did not seem to hold the same reservations that Armsby did. Though Armsby consistently cautioned against creating an environment of government overreach into science, that sort of discussion is not found as prominently in Atwater's writings. It appears that Atwater was so enthralled by the state sponsored scientific research he encountered in Europe that he either neglected to consider potential pitfalls of that system or decided that there were none. Armsby on the other hand was very concerned with the negative effect governmental action could have if it began to tamper with the independence of individual researchers, which he believed would hamper the progress of pure science. He even went as far as writing to the government to ensure this tampering would not occur. This reveals that though Armsby and Wilbur Atwater both filled the role of a political actor seeking governmental support, Armsby's filling of that role is uniquely characterized by the fact that his devotion to pure science caused him to pursue support in a more reserved way than his contemporaries pursued it.

The instances of Armsby filling these three roles coupled with the fact that he clearly possessed broad interests and a long-term vision demonstrates that Armsby certainly deserves the classification of philosopher-scientist. Interestingly, though, the way in which Armsby filled those roles was also affected by his mission to protect and promote pure scientific research. This mission may have lessened the zeal with which he pursued each of the three roles discussed above, but it did not cause him to abandon those roles. He simply found ways to include his pursuit of pure science within the roles of public servant, educational innovator, and political actor. Therefore, Armsby was indeed a philosopher-scientist, but he was a philosopher-scientist deeply concerned about the pursuit of pure and fundamental scientific principles. In order to show that Armsby practiced the pure science he revered so highly, the following chapter will discuss the scientific work Armsby performed with the respiration calorimeter at The Pennsylvania State College.

CHAPTER 4

The Scientific Work of a Philosopher-Scientist

In the previous chapter, it was demonstrated that Henry Armsby's writings demonstrate that he exemplifies the classification of philosopher-scientist. This is due primarily to the broadness of his academic vision and the long-term vision he employed within those writings. Armsby was also seen to fill the roles of political actor, public servant, and educational innovator, just as was seen with his contemporaries: Wilbur Atwater, Ellen Swallow Richards, and Eugene Davenport. However, care must be taken not to characterize Armsby simply as a man constantly occupied by abstract philosophizing at the expense of doing actual scientific research. On the contrary, Armsby held scientific research to be his primary duty. As such, he was also an immensely accomplished scientist in the field of animal nutrition. This chapter seeks to describe the technical scientific research performed by Armsby and his staff in order to demonstrate this scientifically oriented nature of Armsby's career.

In order to accomplish that goal, the main focus of this chapter will be the construction and operation of the instrument which defined Armsby's career and accomplishments; namely, the respiration calorimeter he built at what was then The Pennsylvania State College in 1902. This instrument was a major driver of research interests at the Pennsylvania State College Experiment Station from the time of its construction until 1960 when it was officially closed down. Following an overview of the scientific principles Armsby was interested in uncovering, the story of the construction of the respiration calorimeter will be told. The focus will then shift to the various experiments performed while Armsby ran the station, describing the plan and results of his experimentation with the instrument. All of these discussions will demonstrate

Armsby's scientific knowledge of fundamental principles and experimental design, both key characteristics of an accomplished scientific researcher.

The Fundamental Principles of Armsby's Research

Armsby rose to prominence in the field of animal nutrition with the publishing of his book *Manual of Cattle Feeding* in 1880.[242] The subtitle of this work, "A Treatise on the Laws of Animal Nutrition and the Chemistry of Feeding-Stuffs in their Application to the Feeding of Farm-Animals," belies its aim. Having travelled and studied in Europe, seeing the work done at the experiment stations there, Armsby wished to bring that information to farmers and scientists in the United States. As such, he began a translation of a seminal German work, and this effort ultimately resulted in the creation of a new book – *Manual of Cattle Feeding* – which adapted the same principles of the German work to better fit an American setting.[243] As Armsby explained in the preface to his book, "[the results of German research] are largely inaccessible to the majority of American feeders," therefore he made it "the object of this work to present these results in a connected and systematic form."[244]

Armsby began his systematic discussion of these results by outlining the role of plants, food, and animals in the transference of energy among living things. As he explained, "All forms of life with which we are acquainted, vegetable as well as animal, manifest themselves through the breaking up of more complex into simpler compounds, accompanied by a liberation of energy." The distinction between plants and animals, Armsby explained, is that plants are able to utilize the energy conferred by the sun in order to build new compounds which living things use

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242 Robert L. Cowan, "Henry Prentiss Armsby, 1853-1921: A Brief Biography," *The Journal of Animal Science* 66 (1988): 1837, *JSTOR*, Online (accessed on 29 November 2017).
243 Ibid., 1837.
244 Henry Prentiss Armsby, *Manual of Cattle Feeding: A Treatise on the Laws of Animal Nutrition and the Chemistry of Feeding-Stuffs in their Application to the Feeding of Farm-Animals* (New York: John Wiley & Sons, 1880), iii, *HathiTrust*, Online (accessed on 27 March 2019).

to live and grow. As Armsby said, "In the economy of nature, the office of the plant is to store up energy from the sun's rays in certain complex compounds." [245] Because animals are unable to create these compounds for themselves, they must gain them from elsewhere, either by eating the plants or by eating other animals who themselves had eaten the plants. This, then, is the role of food. As animals use up these life sustaining compounds provided by the plants, the compounds will need to be replaced, therefore, in Armsby's words, "to replace this loss, as well as to supply material for further growth, is the office of food, which may, from this point of view, be regarded as a vehicle for the introduction of supplies…into the body."[246] Armsby provided a helpful analogy for this cycle saying, "In the plant the spring is wound up – in the animal it unwinds and gives out just as much force as was used in winding it up."[247]

Contained within that cycle of energy transference lies the importance of studying nutrition. Armsby explained that importance stating that the object of his book was "to show how much and what kind of food is needed to supply the losses arising under the various conditions to which farm animals are subject."[248] Not only was this the object of Armsby's 1880 book, but the study of rations for farm animals – i.e., "how much and what kind of food is needed" – formed the core of Armsby's personal research. Though food does provide the vital compounds needed for life, it also provides another critical, more fundamental requirement; namely, food provides animals with energy. This sentiment is reflected in Armsby's "The Food Supply of the Future" address, in which he says, "The problem of the food supply is essentially a problem of energy supply."[249] This could be rewritten to say that the problem of nutrition studies is a problem of

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[245] Armsby, *Manual of Cattle Feeding*, 1.
[246] Ibid., 2.
[247] Ibid., 2.
[248] Ibid., 2.
[249] Henry Prentiss Armsby, "The Food Supply of the Future," Proceedings of The American Society of Animal Nutrition (1909), 4, found in Collected Papers of the Animal Nutrition Institute, Eberly Family Special Collections Library, The Pennsylvania State University, University Park, PA.

energy studies, and this is the angle from which Armsby approached the issues of animal nutrition, specifically when he was working with the respiration calorimeter.

In nutrition studies such as the ones performed by Armsby, an important consideration was determining where exactly the energy from a feed was going within the animal. While some of the food energy certainly went into productive processes such as meat production, milk production, or work output, there also existed a level of inefficiency in the energy conversion process. For example, some of the energy is used to keep the animal's body temperature at the proper level. In addition, certain parts of feedstuffs are not digestible by the animal, and that indigestible portion is simply given off in waste products. Therefore, nutritionists sought to determine the amount of the feed which could be utilized by the animal. The chart in Figure 1 below can be used to visualize the way in which nutritionists went about that determination.

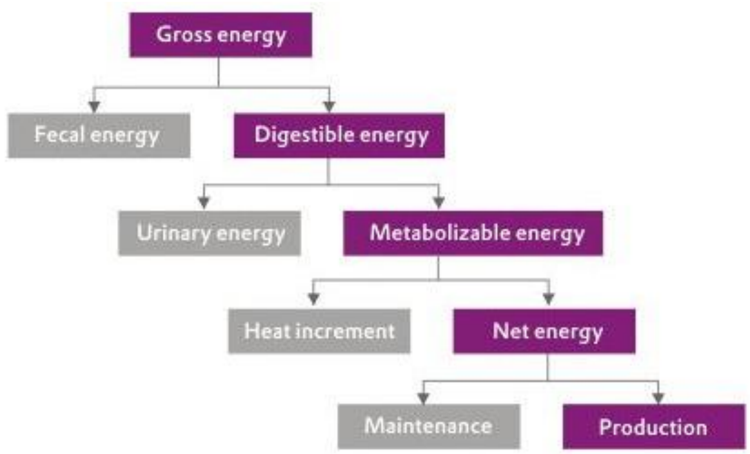

Figure 1: Diagram of Feed Energy Breakdown[250]

This chart shows the various levels of energy which form the basis of discussions on the nutritional energy content of feeds. It also shows the various ways in which that energy content is expended. Starting from the top of the flowchart, the gross energy of a feed is how much

[250] This energy breakdown figure can be found in "Animal Nutrition," *Evonik,* accessed December 12, 2017 http://animal-nutrition.evonik.com/product/feed-additives/en/about/healthy-nutrition/animal-nutrition/pages/energy.aspx.

energy is released when the feed is combusted, which can be measured through the use of an instrument known as a bomb calorimeter. This value represents the overall amount of energy contained in a feed, but during digestion, not all of this energy is utilized by the animal. Following the flowchart down, we see that digestible energy is defined as the gross energy minus the energy lost to fecal matter. From digestible energy, more energy is lost through urine and combustible gases, with metabolizable energy being the amount of energy left over. From there, further energy is lost through the heat produced during digestion and metabolism, with the remaining energy referred to as net energy. After all of the aforementioned deductions of energy loss, it is only this net energy content that is actually utilized by the animal in maintenance, which is the maintaining of proper body function, and production, the creation of products like meat or milk.[251] This net energy value is the value which Armsby believed to be most important in determining a feed's nutritional value, and his experimental work at the respiration calorimeter demonstrated that.

The terminology is not the most important information to be gleaned from the flowchart, though it does contain the terminology used frequently by Armsby. However, the most important aspect of that diagram is that it is helpful in understanding the work of animal nutritionists. The grey boxes in the chart mark values which could be directly measured by researchers and therefore allow for the indirect determination of the values in the purple boxes – the one exception being the gross energy, which can be determined directly, as described above. The collection of solid and liquid waste is relatively straightforward, and could be achieved with relatively simple equipment which collected that waste in such a way as to allow researchers to

[251] This discussion of energy content and the energy breakdown figure both come from: "Animal Nutrition," *Evonik*, accessed December 13, 2017, http://animal-nutrition.evonik.com/product/feed-additives/en/about/healthy-nutrition/animal-nutrition/pages/energy.aspx.

gather it and test its energy content. In addition, through the use of a "respiration apparatus," the gas waste could be measured. Armsby provided the following explanation of this apparatus,

> The principles of this most important apparatus are well illustrated in an ordinary stove, in which the gases coming from the fire may represent those coming from the lungs of the animal. As long as the chimney draws, no smoke escapes from the doors and draughts of the stove, but, on the contrary, the air presses from all sides into the stove, to pass out through the chimney.[252]

Because of this controlled entry and exit of the gases from the stove, exact measurements of the income and outgo could be made, and therefore an observer could "have all the factors needed in order to determine what had been added to the air that entered the stove by the fire inside it."[253] In other words, by knowing the income and outgo of the air with regards to the closed chamber, you could find the difference between the outgo related to the income and determine what had been added to the air by whatever is within the chamber. Therefore, through use of this instrument, the gaseous waste of an animal could also be determined. Taken altogether, the measurements of the solid, liquid, and gaseous waste can be used to determine the metabolizable energy of the feed.

The determination of the heat increment – needed to find the net energy Armsby desired – is more difficult. In order to measure the heat increment, it is necessary to have a means to measure the change in heat production of an animal while it digests its food. It was to make these measurements that Armsby knew he needed to construct the respiration calorimeter. The "respiration" aspect of this instrument is the same as the apparatus described above. A calorimeter, on the other hand, is an instrument which measures heat production during a given process through the monitoring of temperature changes in the calorimeter's chamber. The mechanism by which Armsby's respiration calorimeter accomplished this will be described

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[252] Armsby, *Manual of Cattle Feeding*, 112.
[253] Ibid., 112.

below, but suffice to say for now, once Armsby had built this respiration calorimeter, he had the capability of measuring each of the values in the energy breakdown flowchart. This would allow him to determine the net energy value he believed to be critical for finding the nutritional value of a feedstuff. The desire to have an instrument that could accomplish those measurements was a prime factor in Armsby's decision to construct the respiration calorimeter.[254]

The Construction of the Respiration Calorimeter

In order to gain the support and funding necessary for the respiration calorimeter he believed to be vital for his research, Armsby appealed to the United States Department of Agriculture to engage in a cooperative experimental program. In response, the USDA proposed in 1898 to the Pennsylvania State College Agricultural Experiment Station that Armsby and the station staff "undertake such work [as Armsby proposed] in cooperation with the Bureau of Animal Industry of the United States Department of Agriculture."[255] As a result of this, the USDA offered to provide funding to assist in the construction and operation of the proposed respiration calorimeter and the associated building which would house it. Construction of the building began in 1898 and the first experiment was run with an animal in 1902, with a total price tag for the construction of the instrument and building coming to about $20,000.[256] During the four-year construction period, Armsby and his associates solved a variety of problems associated with the instrument, and this process reveals the scientific prowess possessed by Armsby. An exhaustive description of every specific feature of the respiration calorimeter would

[254] Henry Prentiss Armsby and J. August Fries, "Net Energy Values of Feeding Stuffs for Cattle," *Journal of Agricultural Research* 3, no. 6 (1915): 435-436, Henry Armsby Papers, Pennsylvania State College of Agriculture, Pasto Agricultural Museum, State College, PA. This source provides an excellent discussion of these fundamental principles and their connection to the work performed with the respiration calorimeter.
[255] Winfred W. Braman, *The Respiration Calorimeter* (State College, PA: The Pennsylvania State College School of Agriculture and Experiment Station, 1933), 1, Henry Armsby Papers, Pennsylvania State College of Agriculture, Pasto Agricultural Museum, State College, PA.
[256] Ibid., 2.

be far too time consuming, and as such, the discussion which follows will seek to highlight the best examples of the impressive work Armsby performed in the construction of his instrument.

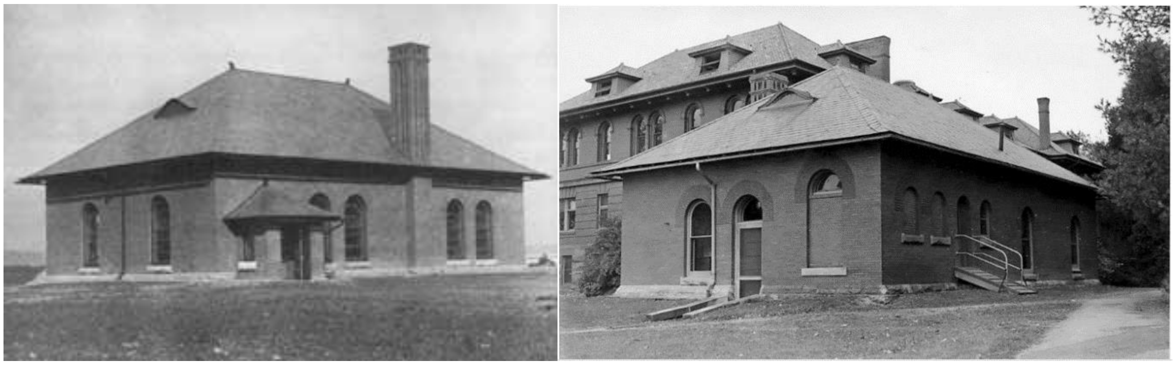

Figure 2: Two Pictures of the Armsby Respiration Calorimeter Building[257]
Left: photo taken c. 1900; Right: photo taken 1939

Upon his decision to construct a respiration calorimeter for his research, Armsby first travelled to various existing respiration calorimeters across Europe. However, he ultimately decided that the best example was the one constructed by Wilbur O. Atwater and Edward B. Rosa at Wesleyan University in Connecticut.[258] The Atwater-Rosa respiration calorimeter, though, was intended for the study of the nutritional requirements of humans, so certain adaptations were needed for Armsby's instrument to test cattle. Armsby explained the necessary "questions [that] had to be solved" in order for that to be possible,

> No cooperation could be had from the subject of the experiment, but everything relating to the conditions inside the apparatus must be adjustable by the observer without. Moreover, for experiments with cattle large amounts of bulky food and excreta had to be introduced into or removed from the apparatus. A further complication arose from the considerable production of combustible gases by ruminating animals, rendering it necessary to provide special means for their determination.[259]

The solutions Armsby devised to overcome these challenges reveal his scientific prowess.

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[257] 1900 photo used in Robert L. Cowan, *Armsby Calorimeter*, https://animalscience.psu.edu/about/history/armsby-calorimeter (accessed on 2 April 2019) and 1939 picture used in Braman, *The Respiration Calorimeter*, 2.
[258] Braman, *The Respiration Calorimeter*, 1.
[259] US Department of Agriculture, Office of Experiment Stations, *Experiment Station Record: Volume XV, 1903-1904* (Washington, D.C., 1904), 1038, *Google Books*, Online (accessed on 1 October 2017).

Regarding the problem of needing everything in the chamber to be controlled from the outside, many solutions were presented. Some of these solutions included the placing of two windows in the instrument – one near the animal's head and one near the rear of the animal – for the observation of the animal. In addition, a number of levers was placed around the chamber to allow the operator to control the various air lock chambers which were used for putting things into the chamber or removing things, as needed.[260]

Related to that issue, as Armsby explained, he also had to find a way to input large amounts of feed into the chamber and remove large amounts of excreta without the active participation of the animal. His solution to this problem, and also the problem of how to input and remove these things without disturbance of the closed system within the chamber, was ingenious. The feed for the animal would be placed into a feed-box which would be placed into an air-lock chamber. The operator would then use a lever on the outside of the chamber to open the air-lock, allowing the animal to access the feed.[261] This air-lock system allowed for the input of feed without compromising the closed system of the chamber.

In order to collect the excreta of the animal, a second air-lock was built into the chamber directly beneath the floor on which the animal would stand. The urine would be collected via hoses and a funnel into a can contained within that lower air-lock. There was also an opening in the floor of the chamber which was fitted into place using rubber sheets holding a trap-door apparatus in place until the weight of feces would open the door, allowing the waste to drop down into the lower chamber, closing and sealing the trap-door once again.[262] The lower air-lock could then be opened by the researchers separately from the main doors of the respiration

[260] Braman, *The Respiration Calorimeter*, 3-15.
[261] Ibid., 9.
[262] Ibid., 11.

calorimeter chamber. Once every 24 hours, a researcher would empty this lower air-lock to collect the waste for chemical analysis, all without disturbing the closed system of the main chamber.[263]

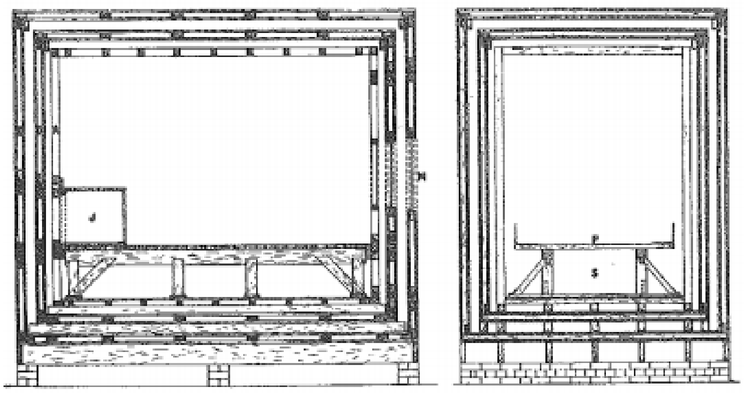

FIG. 6. VERTICAL CROSS-SECTION OF THE RESPIRATION CALORIMETER
Two vertical cross sections of the 3 boxes comprising the calorimeter, M, (in each box) a plate glass window; P, the stall platform with angle irons at the side edges; S, the space for the excreta air-lock beneath the platform.

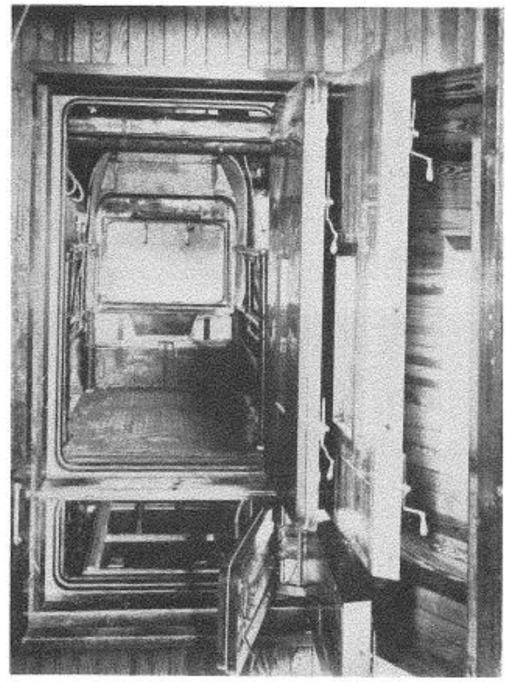

FIG. 9. VIEW OF THE INTERIOR OF THE RESPIRATION CALORIMETER THROUGH THE REAR DOORS

Figure 3: Images of Interior of Respiration Calorimeter Chamber[264]
Left: Cross-section diagrams of chamber (from side and rear) showing the feed box air-lock, labeled "J" and the excreta box air-lock, labeled "S"; Right: Photograph into chamber taken from rear of the instrument with excreta air lock doors visible underneath the main platform.

The issue of measuring the combustible gases given off by the animal in the chamber is closely related to the general mechanism of the respiration apparatus overall, so the two will be discussed in tandem. In a USDA bulletin (dated 1903-1904), Armsby explained the workings of his instrument. The explanation of the respiration apparatus operation which follows is based on Armsby's description of that process.

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[263] Braman, *Respiration Calorimeter*, 12.
[264] Ibid., 8 and 12.

First, the air going into the chamber needed to be analyzed. This was done in three key steps: (1) the incoming air passed over coils of an ice machine which froze the moisture out of the air, drying the air as much as possible, (2) samples were taken from this incoming air and drawn into an aspirator, separate from the air which continued on into the chamber, and (3) the analysis of the air was performed by running the air through U-tubes which contained sulfuric acid and soda-lime. Through chemical reactions not worth detailing at present, the two substances contained in the U-tubes allowed the researchers to determine the amount of water and carbon dioxide present in the incoming air.[265]

For the outgoing air, a very similar process was employed. This process also involved three key steps: (1) the outgoing air was passed through large copper cans which were chilled to -20ºC, by means of a salt water bath, (2) the water from the air froze in these cans, and the weight change of the cans could then be measured to determine the amount of water present in the outgoing air, and (3) the air passed on to a meter pump which utilized U-tubes of sulfuric acid and soda-lime, just as was employed in the incoming air analysis.[266] Because the chamber was air-tight and the only air coming in came through the air-input pipe, the researchers could compare the measurements of the incoming air to the measurements of the outgoing air and determine how much water and carbon dioxide – both products of animal respiration processes – were given off by the animal in the chamber.

In order to measure the combustible gases given off by the animal in the chamber, the outgoing air was then passed from the U-tubes to a long copper tube in which the combustible gases were oxidized, which is chemically similar to combustion, converting the combustible gases to carbon dioxide and water – the products of all combustion reactions. This new amount

[265] USDA, *Experiment Station Record: Volume XV, 1903-1904*, 1041-1042.
[266] Ibid., 1041-1042.

of carbon dioxide and water could be passed through another set of U-tubes, allowing for their measurement. Once that had been done, chemical calculations could be performed which allowed researchers to convert the amounts of carbon dioxide and water into the amount of combustible gases which were originally present. Armsby also mentioned that it took some tweaking to reach the point where this combustible gas determination gave "satisfactory results." Because such a large volume of air was being tested, Armsby ensured that enough platinized kaolin – used for the oxidation reaction – was present in the tube such that the amount was "sufficient to oxidize much larger amounts of [combustible gas] than it will ever be required to in actual use."[267] In this problem-solving endeavor, the technical skill of Armsby is again revealed.

The calorimetric aspect of the respiration calorimeter measured changes in heat which took place inside the chamber. This change was detected through the use of pipes filled with water. Water would flow through pipes at the top of the chamber and the temperature difference between the outgoing water and the incoming water could be used, via some thermodynamic calculations, to determine the heat production of the animal in the chamber. In order for researchers to ensure that any heat change in the chamber was due to the animal and not an external factor, the temperature of the chamber was closely controlled by keeping the air space between the three layers of chamber walls at a constant temperature. This ensured that the chamber was kept in what physical chemists call "adiabatic conditions," defined as a state in which heat is not brought into or out of a closed system such as the respiration calorimeter chamber.[268] Ultimately this allowed for incredibly accurate measurements of heat changes inside the respiration calorimeter.

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[267] USDA, *Experiment Station Report: Volume XV, 1903-1904,* 1042-1043.
[268] Ibid., 1043-1044.

All of this technological ingenuity resulted in an instrument which was described as being "a decided advancement in the method and facilities for [animal nutrition] investigation."[269] Later in that description of the respiration calorimeter, the author – possibly A. C. True, the director of the Office of Experiment Stations at the time – explained its uniqueness and significance,

> In ordinary metabolism experiments the amounts and composition of the food and of the urine and feces are the factors considered. Using this apparatus the amount and composition of the respiratory products, the fuel value of the food, and the energy output of the body are also ascertained, and it is possible to determine the total income and outgo of both matter and energy.[270]

It was this ability to measure the matter and energy within the chamber which allowed Armsby to pursue the research avenues he believed to be most important. As demonstrated in the following section, Armsby was able to use the respiration calorimeter to determine the net energy of various feedstuffs in an effort to discover their relative nutritional values.

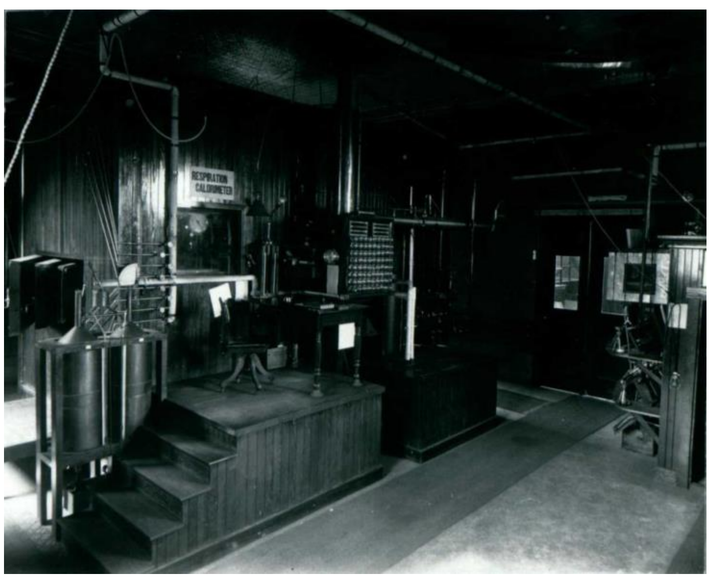

Figure 4: Photograph of Interior of Calorimeter Building (taken 1908)[271]

The feed box air-lock doors are visible on the left. The operator station atop the stairs is visible as well, with the various income and outgo pipes seen along the ceiling and walls.

[269] USDA, *Experiment Station Report: Volume XV, 1903-1904*, 737.

[270] Ibid., 737.

[271] "Respiration Calorimeter 1908," Eberly Family Special Collections Library, The Pennsylvania State University, University Park, PA.

The Nature of Research at the Respiration Calorimeter

In a 1910 bulletin from the Pennsylvania State College Agricultural Experiment Station, Armsby provided a helpful list of the primary research questions which shaped the nature of experimentation he performed with the respiration calorimeter. That list was as follows:

> First: How do different feedings stuffs compare with each other as to their content of energy and the proportion of it which may be rendered available to man through the agency of domestic animals?
> Second: What is the relative efficiency of different types of animals as converters of waste energy into forms suitable for food?
> Third: How do the various conditions under which animals may be kept affect their efficiency as producers of human food?[272]

During his time working at Penn State, Armsby directed numerous experiments dealing with each of these research questions, the first two questions seemingly receiving the most direct attention. Two key experiments are discussed briefly below, one dealing with the first line of investigation and the other dealing with the second.

The first of these experiments is the first official experiment performed with the respiration calorimeter, begun in 1902. The results of this experiment were published in the 1903 USDA Bureau of Animal Industry Bulletin No. 51, entitled "The Available Energy of Timothy Hay." In the "Letter of Submittal" published with that report, Armsby explained that the results presented in the report are preliminary, but because "this first series of experiments with a new and complicated apparatus was much more successful than might have been anticipated," and because the results of the experiment "open up interesting lines of investigation," the researchers felt "justified in presenting [the results] as a report of progress."[273]

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[272] Henry Prentiss Armsby and J. August Fries, *Bulletin No. 105: Influence of Type and of Age Upon the Utilization of Feed by Cattle* (State College, PA: The Pennsylvania State College Agricultural Experiment Station, 1910), 3-4, found in Collected Papers of the Animal Nutrition Institute, Eberly Family Special Collections Library, The Pennsylvania State University, University Park, PA.
[273] Henry Prentiss Armsby and J. August Fries, *The Available Energy of Timothy Hay: Investigations with the Respiration Calorimeter in Cooperation with The Pennsylvania State College Agricultural Experiment Station* (Washington: United States Department of Agriculture, Bureau of Animal Industry, 1903), 3, found in Collected

As mentioned previously, Armsby believed the best way of comparing the nutritional value of various feedstuffs was through their respective net energy content, though he frequently used the synonymous term, “available energy.” In the introductory section of this 1903 bulletin, Armsby explained his understanding of this value: “The available energy of a feeding stuff…may be defined as the amount of energy which it is capable of contributing to the maintenance…of potential energy contained in the tissues of the animal.”[274] In other words, the available energy is essentially the energy from the feed which is available to the animal to be used for various functions; for example, in the case of beef cattle, it is used for the production of meat. Comparing this definition to the energy breakdown figure from earlier, it is clear that Armsby’s “available energy” is the same as that diagram’s “net energy.”

In this first respiration calorimeter experiment, Armsby and his team wished to determine the available energy of timothy hay. They believed this to be a good feed to start with as it was a “fairly definite farm product” and because the researchers believed it would be a relatively simple feed to test.[275] In order to determine the available energy of the timothy hay ration, the researchers had to first account for each of the energy levels above it on the energy breakdown chart. The gross energy was determined through combusting a sample of the feed with a bomb calorimeter, measuring the amount of energy expended. As explained above, throughout the experiment, the researchers also collected the waste products of the cattle. By analyzing these fecal and urinary samples, they could then calculate the amount of metabolizable energy contained in the timothy hay.

Papers of the Animal Nutrition Institute, Eberly Family Special Collections Library, The Pennsylvania State University, University Park, PA.
[274] Armsby and Fries, *The Available Energy of Timothy Hay*, 3.
[275] Ibid., 9.

However, as mentioned, the goal of the experiment was to find the available energy of the timothy hay. In order to find this, Armsby explained, you simply take the calculated metabolizable energy and subtract the amount of energy expended in the digestion of the food, referred to on the energy chart as the heat increment.[276] To determine the amount of energy expended digesting a given amount of feed, the researchers measured the change in heat production as the ration of feed was increased. The experiment was divided into four experimental periods during which the cattle was fed varying amounts of timothy hay. So, by comparing these four periods and their respective heat production values, the heat increment could be found, and the available energy could then be determined. These values were found and were presented in the report's results section.[277] Armsby concluded the bulletin by explaining that they did not believe their results to be fully extensive. Rather they wished these results to be "regarded simply a report of progress" which could be revised and, if necessary, corrected with future investigations.[278] Through the next couple decades of Armsby's directorship, the experiment station staff studied various other feedstuffs in a similar manner as this. But this only formed a third of the lines of investigation Armsby envisioned for his instrument.

The second line of investigation was the effect of animal variety on the efficiency of energy conversion. The 1910 bulletin which contained the research question list provided above is actually a research report entitled, "Influence of Type and of Age Upon the Utilization of Feed by Cattle." Armsby explained in the introduction of this report that the experiments described had compared two types of cattle which he called "the beef type of animal and the so-called 'scrub,' that is with an animal of mixed and unknown breeding but partaking of the dairy type."

[276] Armsby and Fries, *The Available Energy of Timothy Hay,* 53.
[277] This bulletin, like all of Armsby's research reports, is full of tables, but the table which most prominently presents these available energy values can be found in ibid., 56.
[278] Ibid., 60.

He explained that traditional knowledge told farmers that the beef type of steer offered "a distinct financial advantage" but that there was no real scientific evidence which supported that assertion. The investigation of those differences would therefore be the purpose of this experiment.[279]

The comparison of these two animals was made possible through ensuring that the only difference in each case was the animal. As such, each animal received the same daily treatment, including the same ration of the same kind of feedstuff. Repeated weight measurements were made of the two cattle. Armsby remarked that "the measurements show[ed] that the 'scrub' increased more rapidly in length and height than did the pure bred animal, the gain of the latter being more largely due to increase in size of the body."[280] This certainly seems to indicate that the pure-bred animal was more efficiently incorporating the energy of the feed, but Armsby believed the true comparison ought to be based on "the percentage availability of the energy of the feeds consumed."[281] In other words, similar to the way in which Armsby wished to determine the availability of energy contained in the feeds themselves, he also wished to see how efficiently different kinds of animals incorporated that available energy into purposes useful for human use.

In order to accomplish that, over three years, each cattle received a matching ration of timothy hay for part of the year and grain for the other part of the year. Each year, the digestibility and metabolizable energy of each type of feed was determined for each type of cattle. These values were compared to determine whether there were any distinct differences between the animals. For each of these feeds, in terms of digestibility – i.e., the digestible energy from the breakdown chart, a value which refers to the amount of the feed that is readily digested

[279] Armsby and Fries, *Influence of Type and Age*, 4.
[280] Ibid., 4.
[281] Ibid., 5.

by the animal – the results surprisingly offered "no support to the supposed greater digestive capacity of the pure-bred animal."[282] Similar results were found for the metabolizable energy of these feeds for the two cattle. As Armsby explained, "the foregoing figures fail to indicate any material difference in the percentage of total energy of the feed which the two animals were able to metabolize."[283]

A difference did arise once the available energy of each feed for the two cattle was calculated. Using the same process described above, those values were found and Armsby presented their findings stating, "as a whole, they seem to indicate a small but distinct superiority of the pure-bred over the scrub steer as regards the availability of the metabolizable energy of the feed."[284] He also noted that as the cattle aged, the advantage appeared to diminish, and the scrub steer nearly outperformed the pure-bred steer. Though this does appear to confirm traditional knowledge about the superiority of the pure-bred variety, Armsby pointed out that the reasoning behind this advantage was still, at present, only open to speculation. In order to find the reason for this, Armsby stated, researchers ought to "seek for its explanation…in the character of the body substance gained or katabolized." However, he also remarked that "upon this point…respiration calorimeter experiments afford but little information."[285] Therefore, within this experiment, Armsby and his staff had found scientific data which supported traditional knowledge, but he admitted that the work of other researchers would be needed to find the underlying causes of the differences in efficiency observed between pure-bred cattle and scrub cattle.

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[282] Armsby and Fries, *Influence of Type and Age*, 5-7.
[283] Ibid., 7-8.
[284] Ibid., 10.
[285] Ibid., 12.

A 1915 article published in the *Journal of Agricultural Research* provides an excellent overview of the findings of Armsby's research up to that time. Armsby explained in the "Summary" section that 76 experiments had been performed with the respiration calorimeter and provided a list of experimental findings grouped into three major categories. Within the first category, "The Losses of Chemical Energy" – associated with energy lost via feces, urine, and methane – Armsby explained that, among other things, "Neither the losses of energy in the feces nor the total losses showed a distinct relation to the amount of feed consumed" and "Individual differences between animals had no very material influence on the losses of chemical energy."[286] These findings seemed to suggest that the digestible and metabolizable energy of feeds remained relatively constant, no matter the size of the ration nor the variety of animal the feed was given to. This lent credence to Armsby's idea that nutritional value could be determined using energy values found with his instrument.

In the second category, "Losses of Heat Consequent Upon Feed Consumption" – associated with the aforementioned heat increment – Armsby listed many findings including, "The heat production is notably greater during standing than during lying," and "A scrub steer showed a somewhat greater increment of metabolism consequent upon feed consumption than did a pure-bred beef animal."[287] These two specific findings are significant because the first deals with the aforementioned third line of investigation – related to the conditions in which animals were kept – providing evidence that they did investigate that questions, even if it was not treated individually above. The second finding is a direct reference to the second experiment explained above. These two findings, because they relate to heat increment, would potentially have been relatively unknown before Armsby's publishing of these results. Afterall, no other

[286] Armsby and Fries, *Net Energy Values of Feeding Stuffs for Cattle,* 488.
[287] Ibid., 488.

instrument had been built that could measure the heat increment of farm animals, so the significance of these findings also lies in their novelty.

In the third category, “Net Energy Values,” Armsby explained that this article contained a “summary of the average net energy values obtained in these experiments for 11 different feeding stuffs.”[288] To create tables of these net energy values was a primary goal for Armsby as he hoped other researchers or farmers would be able to use those net energy values to determine the nutritional value of the feeds they use. He also said that a “simple method is outlined for computing net energy values, in the absence of direct determinations, from metabolism experiments or from the data of ordinary feeding tables.”[289] This further shows that he hoped others would be able to utilize the results of his research. He wanted fellow agriculturalists to be able to find the most efficient means of feeding their animals, and believed his work to be the beginnings of establishing a system by which that could do just that.

Henry Prentiss Armsby’s Scientific Research and Legacy

Upon consideration of Henry Armsby’s theories regarding animal nutrition, his conception and construction of a respiration calorimeter instrument to meet the needs of his research goals, and the highly technical work he and his staff performed with this instrument, it is clear that Armsby was an accomplished scientific. His renown was widespread, and as one biographer explained,

> Armsby’s work with the calorimeter attracted worldwide attention, and many visitors from other countries came to see his unique apparatus and to benefit from his mastery of the many aspects of energy metabolism and animal nutrition.[290]

[288] Armsby and Fries, *Net Energy Values of Feeding Stuffs for Cattle,* 489.
[289] Ibid., 489.
[290] Cowan, “Henry Prentiss Armsby,” 1839.

Even after Armsby's death in 1921, his research would continue to influence the work of animal nutritionists across the country, and especially his successors at the Penn State Experiment Station.

As research progressed, however, it eventually became clear that certain aspects of Armsby's nutritional theories needed adjustment. This is seen most prominently in an article written in 1933 by E. B. Forbes, Armsby's successor as Director of the Experiment Station. In this article, entitled "The Law of Maximum Normal Nutritive Value," Forbes explained that "evidence [had] been accumulating for many years" which suggested that "foodstuffs can not be evaluated individually" because "net energy values of individual foodstuffs are fundamentally variable." This led Forbes to propose that "the most nearly logical, single, conventional measure of whole nutritive value is the net energy of the nutritively complete ration."[291]

As demonstrated above, Armsby believed that every foodstuff had its own inherent nutritional value and that once that value was found, simple calculations could be performed to determine the nutritional value of a full ration based on the nutritional values of the feedstuffs that made up the ration. However, Forbes believed the problem to be more complicated and went on to explain that a foodstuff may appear to be more valuable upon addition to a ration which is lacking in some nutrient component. For example, if a ration were deficient in protein content, the addition of a foodstuff to the ration which contained protein would cause the added foodstuff to appear to have a higher nutritional content than it would if it were added to a ration which did not need the extra protein. Similarly, a foodstuff already in that insufficient ration may have a lower measured nutritional value than it deserves because it is lacking in that essential protein

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[291] Ernest. B. Forbes, "The Law of Maximum Normal Nutritive Value," *Science* 77, no. 1995 (1933): 306, found in Collected Papers of the Animal Nutrition Institute, Eberly Family Special Collections Library, The Pennsylvania State University, University Park, PA.

component. Forbes therefore believed true nutritional value could only be measured in a ration which was already nutritionally sufficient.[292] This shift marked a notable divergence from Armsby's practices. Forbes believed that rather than simply giving an animal a single type of feed to determine the feed's individual net energy – the route pursued by Armsby – it would be better to measure the net energy of a feed which is part of a ration which provides full nutritional content to the animal. This is pretty clearly a major shift from the line of thinking pursued by Armsby. It is not unusual for scientific thinking to change over time – in fact it could be argued that it is a critical component of scientific advancement – but the work of Forbes is significant in other ways as well, because it also marked another significant shift; namely, in the character of scientists more generally.

During his tenure at the respiration calorimeter, Forbes displayed certain personality differences from Armsby. Armsby may have been a philosopher-scientist whose nutritional research was heavily influenced by his broad knowledge and long-term vision, but Forbes was a much more scientifically focused researcher. One description of Forbes displays this well,

> Dr. Forbes had a thorough grasp of the field of energy metabolism and was one of the foremost men in the field during his time at Penn State. He was constantly seeking to discover why things happened as they did…was a careful and accurate experimenter and promoted these ideals…and devoted himself wholeheartedly to his profession.[293]

In this description, Forbes is not portrayed as a man who deeply considers the social or political dimensions of the problem he seeks to solve. Rather, Forbes is seen to be a man deeply focused on careful experimentation and the perfecting of techniques in the pursuit of answering his research questions. There is, of course, nothing inherently wrong with this attitude. But the comparison of Armsby and Forbes with regard to their attitudes towards the relationship between

[292] Forbes, "The Law of Maximum Normal Nutritive Value," 306.
[293] Robert L. Cowan, "Ernest Browning Forbes, 1849-1966: A Brief Biography," *The Journal of Animal Science* 67 (1989): 852, *JSTOR*, Online (accessed on 29 November 2017).

science and broader academic disciplines provides an insightful view into the shifting nature of scientific research and researchers during the early 20th century.

It appears that soon after Armsby's death, the prominence of philosopher-scientists diminished somewhat. It certainly is not the case that philosopher-scientists completely disappeared, but by the mid-20th century, with scientific research more firmly established in American society, their non-scientific roles were no longer as necessary. As such, their writings and public appearance relied more heavily on the technical scientist aspect of their personality. Therefore, philosopher-scientists rose to a unique prominence during the early phases of the land-grant movement. Though these scientists, like Armsby, were performing critically important and incredibly technical research, they also needed to fill other roles outside of that research. As such, their writings revealed a unique nature which was not seen as commonly in other eras of scientific advancement. A proper appreciation of the two sides of the philosopher-scientist offers important insights into the scientific work of the late 19th and early 20th centuries, and Henry Prentiss Armsby serves as an excellent example of the vital roles played by philosopher-scientists in the institutionalization of scientific research in the United States.

EPILOGUE

Dr. Burt Staniar and Armsby's Importance in Current Research

Though Henry Armsby's work certainly had an impact on the research of his contemporaries and immediate successors, it can rightfully be asked whether Armsby still has any relevance in modern animal nutrition research. Afterall, as was discussed briefly in the final chapter, Armsby's immediate successor redirected the focus of research at the respiration calorimeter away from a number of the ideas being pursued by Armsby. To help discover whether this shift ultimately led to the obsolescence of Armsby's work and impact, I spoke with Dr. Burt Staniar, an animal nutritionist currently working at Penn State. Dr. Staniar also works with calorimetry, though his research primarily deals with horses and utilizes a technique known as "indirect calorimetry" which uses thermodynamic understandings of respiratory products to determine heat production values without the use of a physical calorimeter. When asked whether Armsby's work has any relevance in modern scientific research, Staniar insisted that it did. The resulting conversation revealed much about the importance of studying a figure such as Armsby.

At one point in our conversation, speaking to the importance of Armsby and the respiration calorimeter, Staniar explained, "What makes the Armsby Calorimeter so special…why do nutritionists from around the world continue to come here and want to go see that? Because that was foundational work." Even before he made these comments, earlier in my conversation with Staniar, he provided insight into some ways that Armsby's work has proven to be foundational to the field of animal nutrition, specifically as it relates to his own work. Regarding his own research, Staniar mentioned that his interest in calorimetry comes into play as he looks into different dietary energy sources – such as fats or carbohydrates – and the ways in which horses utilize those energy sources. He explained that calorimetry allows for the determination of how energy sources are utilized by animals, and that that kind of work, in many ways, began with Armsby and his staff. In addition, as mentioned above, Staniar primarily uses indirect calorimetry in his research, specifically while studying the oxygen consumption and carbon dioxide production of horses engaging in athletic activity. Work at the Armsby respiration calorimeter – which could utilize both direct and indirect calorimetric methods – demonstrated that indirect calorimetric methods can be used in lieu of direct calorimetric methods, and as such, the respiration calorimeter played a key role in the foundations of that field of study as well.[294] It was therefore clear to me that though Armsby's theories regarding the nutritional value of feedstuffs was not necessarily correct, and though many of his methods are not employed in the way he used them, the work he performed was still foundational to the field of animal nutrition in other ways. Because of that, he still had an important impact on later generations of scientists, including both Forbes and Staniar, which brings me to another major point in the conversation.

After describing the shift in research methods I had observed taking place during Forbes' tenure – as explained in the final chapter above – Staniar acknowledged that Forbes had moved closer to a more modern understanding of nutrition, explaining that Armsby fell into "a classic mistake that we make all the time in science." Describing the nature of that mistake he said, "We tend to get our blinders on and focus on our particular area and think 'I've got it here, this is the problem.'" But often, Staniar further explained, when scientists step back from their work, they realize that things are generally more complicated than they first appeared.[295] This appears to have been the case for Armsby, but it has also been the case for many scientists.

[294] Oral interview of Burt Staniar, interviewed by Joshua Tonkel, 13 November 2017, University Park, Pennsylvania.
[295] Ibid.

However, Staniar did not intend to say that Armsby's work was unimportant because of that mistake. Rather he pointed out that "Without [Armsby's] work, Forbes wouldn't have had his work." This process has continued for the past century, Staniar explained, saying of scientists "We're always building off of one another." He argued that Armsby helped to create a model, even if imperfect, upon which other researchers could start their own work. He argued that much of scientific research is based around trying to find those relatively simple models to explain relatively complicated concepts. And even if those models are not entirely correct – and initially they often are not – having a model to start building off of allows other researchers to carry on the work begun by the one who made the initial model.[296] Staniar's arguments in this regard reveal the fact that Armsby was an important figure due to his ability to begin answering these fundamental questions of animal nutrition.

When asked about whether it presented a problem to Armsby's legacy that his nutritional theories ultimately proved to be wrong, Staniar explained,

> Was it [Armsby's work] absolutely right? No, but it's not important that it was absolutely right. It's that somebody had the capability of building that [instrument] and investigating that [topic] and doing the work that they did.

Staniar argued that Armsby found new ways to answer questions that many other researchers had also asked, but had no way of answering. And even if nutritional theories eventually shifted away from some of Armsby's ideas, his ability to begin probing the major questions of the field and find a way to start answering them makes him a highly influential figure worth studying, even today.[297]

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[296] Oral interview of Burt Staniar, interviewed by Joshua Tonkel, 13 November 2017, University Park, Pennsylvania.
[297] Ibid.

Staniar also spoke about the fact that misunderstandings are often crucial to the process of scientific research. He argued that there is often no way to know an idea is incorrect until a researcher has pursued an idea and discovered that it was wrong. He even remarked that "some of the best research takes years and years of failures, of experiments that don't work." But he emphasized that this is crucial for the advancement of science, and that it is simply part of the process, even if it prolongs it. As he explained, "Failure is part of the process, and it was a part of the process for the calorimeter too." Because of this aspect of research, Staniar also explained that "Science also takes time. It doesn't happen fast." Just as Armsby worried that the popular demands of the public on scientists could hamper the progress of pure research, Staniar commented that people today want immediate results from the work of scientists. However, he contended that a proper understanding of science reveals that those are unrealistic demands because the best scientific work takes time.[298] The similarity in sentiments between Armsby and Staniar reveals that just as Armsby's research has a legacy in modern research, his feelings about the public demands on science also extend to the present day. As a philosopher-scientist, Armsby's writings are full of his thoughts regarding how science fits into society, and the above sentiments of Staniar reflect that many scientists still have the same feelings which were expressed by Armsby. As such, Armsby's thoughts about science – in addition to his scientific work – offer important lessons and insights for modern researchers.

Because Armsby had such an impact on Penn State and the field of animal nutrition, and because the respiration calorimeter at Penn State was in use for so long – nearly 60 years, from 1902 to 1960 – many lessons can be learned through a study of this history. However, these lessons are not purely historical. A better understanding of the history of science allows for a

[298] Oral interview of Burt Staniar, interviewed by Joshua Tonkel, 13 November 2017, University Park, Pennsylvania.

wider perspective through which to analyze the scientific practices of today. For example, we can better appreciate the effects that arise through the classical education of scientists and the modern more focused approach to scientific education. We can also understand the nature of scientific research as a process of continual and dynamic change via the combined effort of many generations of scientists looking for the answers to fundamental questions all while making mistakes along the way. Because of the importance of these understandings, the discussion of these topics allows Armsby and the respiration calorimeter to continually impact research in a variety of fields, even decades after nutrition research with the instrument came to an end.

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EDUCATION

The Pennsylvania State University, *Schreyer Honors College* **University Park, PA**

College of Liberal Arts, B.A. in History *Class of May 2019*

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Honors Thesis: "Nothing Less Than a Revolution": Henry Prentiss Armsby and the Role of Scientists in Society, 1862-1921

Thesis Supervisor: Michael Milligan

RESEARCH WORK EXPERIENCE

Pasto Agricultural Museum **State College, PA**

Student Intern *Fall 2017*

- Read and analyzed archived materials related to Penn State's Armsby Respiration Calorimeter
- Used Excel to catalogue collection of writings from Penn State's Institute of Animal Nutrition, providing descriptive elements and publishing information for each source
- Included search and sort elements in spreadsheet for use as a finding aid for future researchers
- Created visual presentation outlining a typical experiment run with the instrument

OTHER WORK EXPERIENCE

Ashland, The Henry Clay Estate **Lexington, KY**

Volunteer Tour Guide *June 2017 – Present*

- Led tour groups of 10-20 visitors on hour long tours of the historic home
- Provided interpretation of the site and of Ashland's historical artifact collections
- Received recognition from visitor via online review site commending my ability as a tour guide

Piramal Pharma Solutions, Inc. **Lexington, KY**

Analytical Quality Control Intern *Summers 2017 and 2018*

- Facilitated and participated in key steps of drug product stability program
- Oversaw updates of in-house reference standard inventory system, and implemented new organizational system for better tracking of reference standards
- Organized department's portion of Bring Your Kid to Work Day and led exciting chemistry demonstrations to teach kids about the scientific process

PAPER PRESENTATIONS

"Nothing Less Than a Revolution": Henry Prentiss Armsby and the Role of Scientists in Society, 1862-1921 *December 8, 2018*
Penn State History Undergraduate Research Conference

"Conflicting Views, Common Goals: Marquis L. Wood and the Taiping Rebellion" *March 28, 2018*
Penn State-Pittsburgh Undergraduate Research Symposium in Global Studies

"Nation and Man Divided: Marquis L. Wood and the Taiping Rebellion" *December 2, 2017*
Penn State History Undergraduate Research Conference *Best History 302W Paper Award*

INVOLVEMENT

Penn State Marching Blue Band *August 2015 – Present*

- As Squad Leader, served band by leading members of my section during drill learning process
- Travelled with band to perform at multiple national venues such as the Rose Bowl in Pasadena, CA and the Fiesta Bowl in Glendale, AZ