Botany on the Prairies:
Dr. Reginald Buller's Botanical Wall Charts at the University of Manitoba

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Abstract

This Master's thesis investigates how an English botanist, Dr. Reginald Buller, participated in the flow of New Botany practices and theories to Manitoba. I approach Buller's flow of knowledge through his use of classroom visual aids, in particular, hand-painted wall charts. Visual aids were not secondary to Buller's pedagogy but a key component to the communication of scientific knowledge. I analyze these wall charts and show how they are not only a teaching tool but have an aesthetic history and meaning of their own. Scientists and artists shared pictorial conventions when creating illustrations, due to their close observation of nature. In the particular case of Buller, he was influenced by the Arts and Crafts movement which led to the creation of a unique, utilitarian pedagogical style for Buller's wall charts. These wall charts helped Buller craft engrossing lectures which spread modern botanical thought through the University of Manitoba in a province where education had previously been controlled by clergy.

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Thank you to my friends and family who have supported me through this endeavor. A special thank you to Sarah Romeo and Tammy Sawatzky for their friendship and editing help. And lastly, my partner, Carl Szczerski, who has patiently listened to me discuss botany over the last several years.

Dedication

I dedicate this work to my late grandparents, Karin and Tony Fox, who never tired of my curiosity.

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Introduction

> Nothing is in the understanding that has not before been in the senses!… Only through diligent observation, personal viewing and personal investigation, is it possible to banish the worst enemy of any formative teaching: verbalism.[1]

Botany has had a long visual history. Since Antiquity, healers have used pictorial representations of flora to transfer knowledge about the medicinal properties of various plants. These images have changed drastically over centuries but the goals of communicating information about specific plants has remained. The wide range of visual materials from botanical science including herbals, floras, and morphological illustrations have been admired for their aesthetic appeal. Botanical illustrations have also captured the eye of the public. Motifs from botany have made their way into the realms of art and design, being developed into fabric prints, decorative arts, and posters.

Interestingly, botanical illustrations were not always created by artists but rather by the scientists directly. Botany was a science which required some artistic prowess by its practitioners. Botanists needed to sketch their observations from the field and laboratory work as well as develop illustrations for publications and lectures. Art historian Martin Kemp was one of the first scholars to specialize in the connections between art and science. Integral to my study is Kemp's concept that scientists and artists "share so many ways of proceeding: observation, structured speculation, visualization, exploitation of analogy and metaphor, experimental testing, and the presentation of a remade experience in particular styles."[2] This theory posits that artists

[1] "Nichts ist im Verstande, was nicht zuvor in den Sinnen war! ...Nur durch fleißiges Beobachten, durch Selbstschauen ist es möglich, den schlimmsten Feind alles geistbildenden Unterrichts aus der Schule zu verbannen: den Verbalismus." Otto Schmeil, in *Seybold*, op. cit. (12), 243 translated and quoted in Massimiano Bucchi, "Images of Science in the Classroom: Wallcharts and Science Education 1850-1920," *The British Journal for the History of Science* 31, no. 2 (1998) 167.

[2] Martin Kemp, *Visualizations: The Nature Book of Art and Science* (Oxford; New York: University of California Press, 2001) 4.

and scientists look at the world and communicate it in similar ways with similar techniques. This was particularly true for the natural sciences of early twentieth century as there was an emphasis on observation of the natural world. In my discussion, I will investigate an English-Canadian botany professor, A.H. Reginald Buller (1874-1944), as a scientist who was visually aware and used artistic formal techniques to create scientific illustrations.

One unique form of botanical illustration is the educational wall chart. Wall charts were developed in the 1820s in Germany for a variety of subjects.[3] They quickly grew in popularity due, in part, to a shift in pedagogical theory moving away from purely lecturing in courses.[4] In conjunction with the change in pedagogy, educational systems in Europe were evolving, expanding to include more students and increasing the number and size of schools. Wall chart usage grew beyond Germany and quickly spread throughout Europe and into North America. They became especially popular within natural sciences as several prominent scientists worked on mass-produced lithograph sets for purchase by educators. By the twentieth century, many botany professors teaching modern botanical techniques owned at least some wall charts, if not several sets.

Wall charts offer an uncommon glimpse into the combination of education, art, and science. However, these visual aids can be categorized as images that have been "unclaimed" by art historians and art organizations despite the fact that they "are readable as constructions of visual knowledge," as noted by visual culture historians Caroline Jones and Peter Galison.[5]

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[3] Massimiano Bucchi, "Images of Science in the Classroom: Wallcharts and Science Education 1850-1920," *The British Journal for the History of Science* 31, no. 2 (1998) 163.

[4] Erik Zevenhuizen, "Uit de Drukpers En van de Tekentafel: Botanische Onderwijsplaten van Nederlandse Universiteiten" (University of Amsterdam, 2005)

[5] Caroline A. Jones and Peter Galison, eds., *Picturing Science Producing Art* (New York: Routledge, 1998) 6.

Visual products are important artifacts and can offer insight into the practices of the period. These visual aids deserve a closer look because of their unusual position at the juncture of several disciplines. I will investigate the hand-painted watercolor wall charts designed by Buller, and analyze how these images fit into the larger history of New Botany as both works of art and scientific educational aids. I will also examine the career or Dr. Buller as a vector for bringing modern science pedagogy and practice to Manitoba at the turn of the twentieth century.

Hailing from Birmingham, England, Dr. Reginald Buller was a botany professor in Manitoba from 1904 to 1936. He was highly active in the international scientific community and well regarded as a lecturer and researcher across Europe and North America. Buller was educated at some of the most respected schools that specialized in New Botany in England and Germany, including Mason Science College and Leipzig University. Throughout his education Buller learned the most up-to-date techniques in botanical science. Upon taking up his position at the University of Manitoba, he then introduced these new methods to Winnipeg, where science education had been previously controlled by clergy. Buller introduced new teaching methodologies to Manitoba, in part, through the use of botanical wall charts, modernized botanical scientific practice and pedagogy on the Canadian prairies, and brought the world's attention to Winnipeg's mycological research.[6]

As part of his education, Buller learned the importance of visual materials in teaching and embraced this concept in his own classroom. He prided himself on his own artistic work from his book illustrations to his wall charts. Buller took great care to ensure that any time he was communicating scientific knowledge, he provided quality visuals to make his point. Buller owned several sets of mass-produced lithograph wall charts for use in his classes. In addition to

[6] Estey, *Essays on the Early History of Plant Pathology and Mycology in Canada* (Montreal: McGill-Queen’s University Press, 2014) 277.

the lithographed charts, Buller and his assistants also painted many of their own wall charts for classroom use. Professors creating their own visual aids was fairly common and some laboratories even hired illustrators to paint wall charts for their specific needs.[7] Most custom wall charts were meant for higher level classes or to support the professor's new research.[8] Buller's watercolor versions are unique because they are generally his own interpretations of topics covered by exiting charts. Buller was precise and decisive in the development of his charts, always creating clear and simple compositions which mimicked his lecturing style of being concise and easy to follow.

Buller also developed a unique pedagoglogical artistic style for his wall charts. While at Mason Science College, Buller was introduced to the scientific and artistic work of German zoologist, Ernst Haeckel (1834-1919). In Haeckel's work Buller came across the concept of aesthetically pleasing scientific images, especially through his hand-colored magnified microscopic images of radolarians. Buller later combined this concept of aesthetic utilitarian educational images with the Arts and Crafts style. The Arts and Crafts movement emphasized the use of natural forms and a move away from industrialization. The movement was influenced by the theories of art critic John Ruskin who believed art should communicate an appreciation of nature. The theories of Ruskin interested Buller as he had several of the critic's books in his library.[9]

The Arts and Crafts movement was at the height of its popularity while Buller was in school in England and Germany, and Birmingham, Buller's hometown, was a center of Arts and

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[7] National Library of the Netherlands, "The Art of Knowledge: Educational Botanical Wallcharts 1879-1960 - The Heyday of Educational Wall Charts," *Memory of the Netherlands*, http://www.geheugenvannederland.nl/

[8] Ibid.

[9] T. Johnson, *Catalogue of the Buller Memorial Library* (Ottawa: Canada Department of Agriculture, 1965) 79.

Crafts art and architecture. Additionally, Birmingham was the birthplace of one of the movement's key figures, Edward Burne-Jones (1833-1898). Buller was inspired by the theories designs of Burne-Jones and William Morris, another significant Arts and Crafts artist, and later implemented the movement's tenets into his own illustrations. The resulting visual aids emphasized simple compositions using preindustrial techniques to deliver his modern New Botany lectures.

The investigation of botany has experienced a resurgence in academic and popular culture over the past decade. After a stint of popularity in the mid-twentieth century, research into the history of botany experienced a lull until recently. As a result of this wane in scholarship, there are few overarching histories of botany. The most recent is botanist A.G. Morton's *History of Botanical Science: an Account of the Development of Botany from Ancient Times to the Present Day* from 1981.[10] When Morton wrote his book he was "struck by the lack of a history of botany as seen from the standpoint of today." While Morton's text does offer a concise overview of the field, it is clearly from a botanist's point of view and focuses mainly on botanical discoveries. More recent studies focus on specific time periods, places, and objects, leaving a patchy field of scholarship. Popular areas of botanical to study have been cultural histories during colonial expansion by scholars such as Jim Endersby and Londa Schiebinger as well as gender studies by researcher like Ann Shteir and Tina Gianquitto.[11]

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[10] A. G. Morton, *History of Botanical Science: An Account of the Development of Botany from Ancient Times to the Present Day* (London; New York: Academic Press, 1981) v.

[11] Jim Endersby, *Imperial Nature: Joseph Hooker and the Practices of Victorian Science* (University of Chicago Press, 2008), Londa L. Schiebinger, *Plants and Empire: Colonial Bioprospecting in the Atlantic World* (Cambridge, Mass; London: Harvard University Press, 2007), Ann B. Shteir, *Cultivating Women, Cultivating Science: Flora's Daughters and Botany in England, 1760-1860* (Baltimore: Johns Hopkins University Press, 1996), and Tina Gianquitto, *Good Observers of Nature: American Women and the Scientific Study of the Natural World, 1820-1885* (Athens, GA: University of Georgia Press, 2007).

Finally, a note on terminology in this paper. Although it has become a much debated word, I will be using the term science throughout this paper. There is much literature on topic of what science is and how to define it. Philosophers of science like Thomas Kuhn, Karl Popper, and Paul Feyerabend have fervently argued over the progression of science. As Kemp notes, the term science has been used in such varied ways as to make the term "crude," however it is convenient.[12] In this paper, I will use the term science in the early twentieth century sense, as Buller and his contemporaries would have understood it, indicating a systematic and objective investigation of natural phenomena using the scientific method.

I will focus on the study of plants in the late nineteenth and early twentieth centuries. Scholars from various disciplines have been intrigued by botany and there is a small but robust literature on the topic. During the nineteenth century, the practice of natural investigation changed drastically. The values of epistemology and objectivity came to the forefront and "naturalists" became "scientists" as the scientific method was developed. At this point the fields of botany, geology, chemistry, and physics, to name a few, became more distinct and defined.

Historiography

In chapter one, I trace the development of New Botany and the movement of these methods to Canada. New Botany is a term that encompasses a shift in thought and practice of botanical science that came out of Germany, focusing on evolutionary theory particularly in relation to the internal structures of plants. New Botanists also emphasized original research, especially in the laboratory, and relied upon advances in microscope technology. New Botanists

[12] Kemp, *Visualizations,* 5.

relied more heavily on advances in technology which allowed for new ways of investigating plant life.

Dr. Buller was influenced by his German education to include visual material in his lectures, creating unique, dynamic, and interesting classes. Eugene Cittadino's *Nature as the Laboratory: Darwinian Plant Ecology in the German Empire, 1880-1900* offers an excellent analysis of the beginnings of New Botany and the careers of some of the lesser known key figures of the movement.[13] Cittadino's book however is not a history of New Botany, in fact, he does not use the term in the text, rather his purpose is to layout the evolution of plant ecology. The fields are closely linked and many of the scientists he mentions were important New Botanists.

Scholarship for the history of Canadian botany is even more sparse and piecemeal than that for international botany. Suzanne Zeller, R.H. Estey, Vittorio M. G. de Vecchi, and Richard Jarrell have all addressed various aspects of the history of science in Canada.[14] Chapter one will also help address the lack of literature on Canadian botany in the early twentieth-century. Manitoba specific studies are even fewer with Harry Duckworth and Gordon Goldsborough's "Science Comes to Manitoba" being the only article available on the topic.[15] Duckworth and Goldsborough discuss the development of science education in Manitoba, with a focus on the creation of the University of Manitoba. Understandably, Buller is mentioned by Duckworth and

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[13] Eugene Cittadino, *Nature as the Laboratory: Darwinian Plant Ecology in the German Empire, 1880-1900* (Cambridge: Cambridge University Press, 1990).

[14] Suzanne Zeller, *Inventing Canada: Early Victorian Science and the Idea of a Transcontinental Nation* (Montreal, QC, CAN: McGill-Queen's University Press, 2009), R. H. Estey, *Essays on the Early History of Plant Pathology and Mycology in Canada* (Montreal: McGill-Queen's University Press, 2014), Vittorio M. G. de Vecchi, "The Dawning of a National Scientific Community in Canada, 1878-1896," *HSTC Bulletin: Journal of the History of Canadian Science, Technology and Medicine* 8, no. 1 (26) (1984): 32–58, Richard A. Jarrell, "Science Education at the University of New Brunswick in the Nineteenth Century," *Acadiensis* 2, no. 2 (April 4, 1973): 55–79.

[15] Harry Duckworth and Gordon Goldsborough, "Science Comes to Manitoba," *Manitoba History*, no. 47 (2004)

Goldsborough, as becoming, "the most distinguished scientist among [the original six professors hired], and perhaps the most distinguished scientist that the University of Manitoba has ever had."[16] My study adds to this literature by investigating the history of botany in Manitoba in the first half of the twentieth-century, focusing on how Buller took up the pedagogy of New Botany and used visual aids to communicate scientific knowledge at the University of Manitoba.

In chapter two, I analyze Buller's education and career, with an emphasis on his interest in visual materials. Buller was a significant figure within the scientific and educational communities of Manitoba and although he received opportunities to work elsewhere, he remained in Winnipeg and used his innovative pedagogical approach to build and expand the science department. The literature on Buller is limited, consisting of a small number of articles, mentions in several books, and many obituaries. Dr. Gordon Goldsborough's "Reginald Buller: The Poet-Scientist of Mushroom City" is the most comprehensive biography of Buller available.[17] Goldsborough situates Buller as an important figure in the development of Manitoban science education. R.H. Estey also wrote a short biographical article, entitled "A. H. R. Buller: Pioneer Leader in Plant Pathology."[18] Estey also mentions Buller several times in the Manitoba sections of his book *Early History of Plant Pathology and Mycology in Canada*.[19] Buller's many obituaries were very brief but a number, including F. T. Brooks' for the Royal Society and Harold J. Brodie and Charles Lowe's written for the American Association for the

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[16] Duckworth and Goldsborough, "Science Comes to Manitoba," 8.

[17] Gordon Goldsborough, "Reginald Buller: The Poet-Scientist of Mushroom City," *Manitoba History*, no. 47 (Spring/Summer 2004)

[18] R. H. Estey, "A. H. R. Buller: Pioneer Leader in Plant Pathology," *Annual Review of Phytopathology* 24, no. 1 (1986)

[19] Estey, *Early History of Plant Pathology and Mycology in Canada.*

Advancement of Science, were more thorough.[20] Buller is also favorably, albeit briefly, mentioned, in a small number of botany texts.

The Buller fonds at the University of Manitoba Archives & Special Collections were the major resource for me and the cornerstone for my project. The Archives hold two meters of Buller's correspondence from 1905 to 1943, as well as his collection of hand-painted watercolor and mass-produced lithograph wall charts. I have used his correspondence to explain his interest in visualization and to illustrate how he implemented it in pedagogy. Additionally, the history of the University of Manitoba is an important component in any discussion of Buller's career. Several fairly comprehensive histories of the University have been published including those by Henry Duckworth, William Morton, and Richard Johnson.[21] Chapter two is intended to fill a gap in the literature on this important figure in Manitoba history, and approach his career from a new viewpoint by investigating his pedagogy and visual materials.

Chapter three will offer an analysis of botanical wall charts as carefully designed aesthetic objects as well as pedagogical visual aids. Research into this field is multidisciplinary, including work from art history, visual culture, and science history. Interest in the overlap between scientific illustrations and art has been growing steadily in recent years and a robust literature is developing. New developments in art history and visual culture have begun to view scientific illustrations in their own right and as worthy of study. Museums and archives are leading the way by hosting exhibitions relating to the aestheticisation of scientific images and the

[20] F. T. Brooks, "Arthur Henry Reginald Buller, 1874-1944," *Obituary Notices of Fellows of the Royal Society* 5, no. 14 (1945) and Harold J. Brodie and Charles W. Lowe, "A. H. Reginald Buller," *Science* 100, no. 2597 (1944): 305–7.

[21] Henry E. Duckworth, *The University of Manitoba: An Illustrated History* (University of Manitoba Press, 2001); William Lewis Morton, *One University: A History of the University of Manitoba, 1887-1952* (Toronto: McClelland & Stewart, 1957); William Lewis Morton, "The Founding of the University of Manitoba," in *Higher Education in Canada: Historical Perspectives*, ed. Alexander Douglas Gregor and Keith Wilson, Monographs in Education 2 (Winnipeg: University of Manitoba, 1979), 7–12; Richard A. Johnson, "The Broadway Site of the University of Manitoba: Origins and Demise," *Manitoba History*, no. No. 51 (February 2006): 20–27.

scientification of aesthetic images. Curators are also developing a literature in the form of complementary exhibition catalogues. Chapter three will offer an important addition to scholarship on the visual culture of botanical illustration as a pedagogical tool. Scientific illustration and its connection to fine art has been well studied, most notably by Martin Kemp. Other scholars, including Barbara Maria Stafford, Linda Henderson, Serena Keshavjee, and Oliver Botar have also noted the connections between science and art.[22] These authors delve deeper into the analysis of scientific imagery to explore the connections between artists and scientific practice, the relationship between scientific illustrations and text, and the complex cultural conditions under which the illustrations were created. Kemp argues that the central intellectual and observational concerns between scientists and artists are the same.[23] The fact that Buller hand illustrated his wall charts is particularly important to the study of art and science, which is a central aspect of my thesis.

In *The Technical Image: A History of Styles in Scientific Imagery,* Horst Bredekamp questioned how terms used to describe illustration are influenced by art historical efforts at the turn of the twentieth century to define style in visual art by scholars including Heinrich Wölfflin, Alois Riegl, and Erwin Panofsky.[24] Understanding the issues around utilizing an art historical

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[22] A selection of works that focus on scientific illustration and art includes, Wilfrid Blunt and William Stern, *The Art of Botanical Illustration* 2nd ed. (New York: Arch Cape Press: 1993), Serena Keshavjee, "La Vie Renaissant de la Mort": Albert Besnard's "Non-Miraculous" History of Creation," in Picturing Evolution and Extinction: Regeneration and Degeneration in Modern Visual Culture, eds. Fae Brauer and Serena Keshavjee (Cambridge: Cambridge Scholars Publishing, 2015), 61-82, Linda Henderson, *Duchamp in Context: Science and Technology in the Large Glass and Related Works* (Princeton, NJ: Princeton University Press, 1998), Barbara Maria Stafford, *Artful Science: Enlightenment, Entertainment, and the Eclipse of Visual Education* (Cambridge, MA: MIT Press, 1994), Martin Kemp, *The Science of Art: Optical Themes in Western Art from Brunelleschi to Seurat* (New Haven: Yale University Press, 1990), and Oliver Botar, "László Moholy-Nagy's New Vision and the Aestheticization of Scientific Photography in Weimar Germany," *Science in Context* 17. no. 4 (2005) 525-556.

[23] Martin Kemp, *The Science of Art: Optical Themes in Western Art from Brunelleschi to Seurat* (New Haven: Yale University Press, 1990) 1.

[24] Horst Bredekamp, Vera Dünkel, and Birgit Schneider, eds., *The Technical Image: A History of Styles in Scientific Imagery* (Chicago: University of Chicago Press, 2015) 18-19.

term for scientific illustrations has led to the use of a more neutral terminology for scientific illustration. These neutralized terms include visualization instead of art historical vocabulary, which I have adopted in this thesis in an attempt to avoid cultural baggage. This has ushered the beginnings of a new vocabulary for studies into the visual cultures of science. Furthermore, the literature on the history of visual resources in science education is considerably less developed. *Visual Cultures of Science: Rethinking Representational Practices in Knowledge Building and Science Communication* edited by Luc Pauwles is an excellent collection of essays analyzing objects and their visual connection to science education or communication.[25] Pauwles asserts that visual representations are "an essential part of scientific discourse" and that their value be judged on their functionality rather than their replication of nature.[26]

Considering wall charts specifically, author of *Botanical Art from the Golden Age of Discovery* Anne Laurent stated, “I assumed my book wasn’t the first. But it was.”[27] Laurent's book was published in 2016, only a few months prior to the completion of this thesis, showing the dearth of scholarship on the topic. Laurent focused on collections of several European universities and researched their wall chart sets, some of which were still being used. She compiled a beautifully illustrated book, organized by plant family, to show the differences in how various plants were depicted. Although an asset simply for its cataloguing efforts, Laurent’s book lacks scholarship badly needed in the field. Massimiano Bucchi’s article "Images of Science in the Classroom: Wall Charts and Science Education 1850-1920" is also key as one of

[25] Luc Pauwels, ed., *Visual Cultures of Science: Rethinking Representational Practices in Knowledge Building and Science Communication* (Hanover, NH: Dartmouth College Press, 2006).

[26] Luc Pauwels, “The Role of Visual Representation in the Production of Scientific Reality,” in *Visual Cultures of Science: Rethinking Representational Practices in Knowledge Building and Science Communication*, ed. Luc Pauwels (Hanover, NH: Dartmouth College Press, 2006) vi-vii

[27] Anna Laurent, *Botanical Art from the Golden Age of Scientific Discovery* (Chicago: University of Chicago Press, 2016) 9.

the few pieces of scholarship directly addressing wall charts.[28] Bucchi describes the rise of commercial wall chart sets which began in Germany in the 1820s and quickly grew in popularity. Buller was living in Germany from 1897-1900 while pursuing his PhD and would have seen many of these set in use, but when he began his teaching career at the University of Manitoba he designed and drew his own teaching aids. Rudolf Schmid also researched wall charts, publishing one conference abstract and one book review which included information on the topic.[29] It is possible that so little has been written about wall charts because these objects are considered simply functional educational aids not of scholarly interest. Due to their multidisciplinary nature, wall charts may have fallen into a "no-man's land" of unclaimed scholarship.

Wall charts exist at a unique intersection of art, science, and education. Further work on this topic will yield insight into each of these areas through a different lens. Research on the subject is new and much work remains to be completed. These visual aids became popular through the influence of New Botanists and a shift in pedagogical methodologies. Through his use of botanical wall charts and by attempting to forge his own Arts and Crafts-influenced style, Buller modernized botanical education and knowledge on the Canadian prairies.

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[28] Bucchi, "Images of Science in the Classroom."

[29] Rudolf Schmid, "Wall Charts (Wandtafeln): Remembrance of Things Past," *Taxon* 39, no. 3 (1990) 471–72. and Rudolf Schmid, "The Phenomenon of Botanical Wall Charts (Botanische Wandtafeln) from 1874 to 1914 - Abstract," *American Journal of Botany* 72, no. 6 (1985): 879–80.

Chapter 1: The Advent of Modern Botany

The study of plants has fascinated humans and has been a focus of inquiry for thousands of years. However, the form that this inquiry has taken has shifted drastically over time, particularly with the growing belief in empiricism and the redefinition of scientific practice. Although the study of plants has been undertaken for millennia, its formation into a respected, independent branch of study is relatively recent. In this chapter, I will investigate botany's development into a modern experimental science during the nineteenth century in England, Germany, and Canada and how these shifts in the field corresponded with changes in the post-secondary educational system in each country. I will also discuss how although Canadians borrowed heavily from structures in Europe, these systems developed a uniquely Canadian style in the Dominion.

Studies into plant life are frequently linked to a practical application of botany from medicine to agriculture. Since Antiquity, botany had been used to identify plants and their possible medicinal properties. Botany continued to have a distinct history within medical fields up through the nineteenth century and continues to some extent, today. Unsurprisingly, agricultural practice has also been closely tied with botany. This aspect of botany has also developed separately from medicinal botany. However, agricultural botany has continued to flourish into the twenty-first century, being an integral component of agricultural programs throughout North America. For the purposes of this discussion, I will be focusing on "pure" botany, or the study of plants without direct application to another discipline, and its development into modern botanical science in the late nineteenth and early twentieth centuries.

In the early part of the nineteenth century botany could be separated into three main fields of study: systematic, economic, and physiological.[30] Systematic botany focuses on distinguishing and organizing plant species, economic botany is concerned with the practical uses of various plants, while physiological botany studies function and structure of plants.[31] Botanists' main goal was to identify and catalogue plant species across the globe, particularly within regions newly acquired by European powers.[32] However, because botany was considered mainly an inventory science, along with geology and zoology, its other aspects were not avidly pursued.[33] Botany matured late into the group of inventory sciences due to the field's general lack of an agreed upon nomenclature.[34] Many scientists tried to develop a naming system but it was not until Carl Linnaeus' (1707-1778) publication of *Systema Naturea* in 1735 that a nomenclature became widely accepted. Although there was some debate regarding Linnaeus' system, it eventually became the standard nomenclature within botany making the transfer of research and information between scientists much easier.[35] As a standardized nomenclature took hold, the science swiftly became popularized.[36] Although it had gained popularity, botany remained highly descriptive and this quality relegated the science to a secondary status within the community.

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[30] Suzanne Zeller, *Inventing Canada: Early Victorian Science and the Idea of a Transcontinental Nation* (Montreal, QC: McGill-Queen's University Press, 2009) 185.

[31] Ibid.

[32] Jim Endersby, *Imperial Nature: Joseph Hooker and the Practices of Victorian Science* (University of Chicago Press, 2008) 18.; Bower, England and German Botany, 136.

[33] Zeller, *Inventing Canada*, 4.

[34] Ibid., 185.

[35] There is a wealth of scholarship on Carl Linnaeus and his binomial nomenclature, which will not be discussed here. For more information, see Lisbet Kroener, *Nature and Nation.*

[36] Ann B. Shteir, *Cultivating Women, Cultivating Science: Flora's Daughters and Botany in England, 1760-1860* (Baltimore: Johns Hopkins University Press, 1996) 13.

Botanists at the time were also eager to find answers to questions that their explorations had raised. Traveling botanists had found the same species of plants around the world, sometimes in remote areas, and some had discovered phenotypically similar plants that were actually different species across similar climatic bands.[37] Finding the patterns in these global plant dispersals enabled botanists begin to raise the science's prestige.[38] Botanists also focused on the economic aspects of plant life by attempting to identify plants that would be useful exports from colonies and trying to modify popular colonial plants to grow in non-native climates.

In the early nineteenth century, botany gained much favorability amongst the general public as a hobby because it was considered easy to learn. Botany was also thought to be beneficial for its aesthetic and educational qualities, and its perceived salubrious effects. Many women also used the pastime as an acceptable way to gain scientific education, which was thought to be a polite alternative to more scandalous or frivolous activities.[39] Botany also became particularly popular in the latter half of the century in England with a flurry of botanical publishing.[40] A new genre of book was created, focusing on botanic interests for women.[41] Several women also started careers as popular botany writers. With the increased female presence within botany, the science became thought of as feminized and simplistic, therefore gaining an unfavorable reputation within the science community leading to a differentiation

[37] Endersby, *Imperial Nature,* 18.

[38] Ibid.

[39] Shteir, *Cultivating Women*, 2.

[40] Ibid.

[41] Ibid., 19.

between the botanist and the botanophile.[42] However, the mid-1850s brought about significant change within botany to heighten the field's scientific prestige.

During this period the sciences, including botany, became professionalized.[43] Early in the century receiving no fee for scientific pursuits was the ideal concept of a gentleman, and although there had been some teaching positions available through universities previously, the salaries were not living wages and needed to be supplemented with attendance fees.[44] Many professors waited by the door of the classroom after each lecture to receive additional payment from students after class.[45] Some research positions were available through institutions like Royal Botanic Gardens, Kew, however these were few and far between. Many botanically inclined students were directed to train in medicine rather than botany as a way to have a profession to fall back on.[46] Job prospects changed into the nineteenth century as university systems across Europe expanded and more research laboratories or institutes were founded, giving rise to more laboratory trained botanists as well as greater opportunity for employment. This growth in the employment sector did not keep up with the increase in botany graduates, however. Additionally, the concept of the self-taught, independently wealthy botanist working only for the pursuit of science was not totally abandoned, keeping wages relatively low.[47]

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[42] Shteir, *Cultivating Women*, 32. For a more thorough discussion on gender in botany see Ann Shteir's, *Cultivating Women, Cultivating Science*, and Ann Shteir and Bernard Lightman's, *Figuring It Out*.

[43] There is debate over the specific events which lead to the professionalization of science which will not be discussed in this paper. For more information, consult Jim Endersby, *Imperial Nature: Joseph Hooker and the Practices of Victorian Science.*

[44] Endersby, *Imperial Nature,* 2 and 11.

[45] Endersby, *Imperial Nature,* 11; Sheldon Rothblatt, *The Modern University and Its Discontents: The Fate of Newman's Legacies in Britain and America* (Cambridge: Cambridge University Press, 1997) 357.

[46] W. G. Farlow, "The Change from the Old to the New Botany in the United States," *Science* 37, no. 942 (1913) 79.

[47] Endersby, *Imperial Nature,* 2.

Although struggling for a livable wage and career prospects, by the 1840s botany was maturing into a respectable profession.[48] More changes were also to come within the field during the century concerning methodology.

One of the most significant events for biology was Charles Darwin's (1809-1882) publication of *On the Origin of Species* in 1859, which explained evolution by natural selection. Botanist W.G. Farlow commented in 1915:

> …in 1859 the *Origin of Species* fell like a bomb in the camp and shattered time worn theories. That the variations and adaptations of plants and animals were not for the benefit of man, but for the benefit of the plants and animals themselves, was a dreadful heresy. The violence of the controversy caused by Darwin's great work was something of which the present generation can have no conception.[49]

On the Origin of Species was not universally accepted but did meet with wide acclaim within the field of botany in part due to Wilhelm Hofmeister's (1824-1877) previous work discovering the alternation of generations of plants. Hofmeister's discovery was so groundbreaking because of its uniformity among other plant species and its ease of observation by other botanists.[50] Because of this, many botanists saw Darwin's evolutionary theories as a link to Hofmeister's work.[51] Darwinism also excited scientists working on the geographic distribution of plants. Many botanists were mapping plant distribution around the globe and analyzing similarities in plant species and their climates. The consideration of plants having common ancestors helped explain why similar plants were discovered around the globe in similar climates.[52] Darwinism expanded

[48] Eugene Cittadino, *Nature as the Laboratory: Darwinian Plant Ecology in the German Empire, 1880-1900* (Cambridge: Cambridge University Press, 1990) 21.

[49] Farlow, "The Change from the Old to the New Botany," 80-81.

[50] Cittadino, *Nature as the Laboratory,* 13.

[51] F. O. Bower, "English and German Botany in the Middle and Towards the End of Last Century," *New Phytologist* 24, no. 3 (August 1, 1925) 131.

[52] Cittadino, *Nature as the Laboratory,* 21.

botanists' way to conceive of plant science. Thus, botanists began further investigation into the physiological and anatomical aspects of plants rather than focusing solely on taxonomy.

Also integral to botany's transformation was the colonial expansion of European powers. Although European countries had been expanding for years, functioning laboratories were now being established in tropical lands allowing scientists to travel to outpost laboratories to study and research instead of relying solely on dried specimens sent to them from abroad.[53] Tests and experiments could be performed immediately at field station laboratories, allowing for more accurate research as well as widening the scope of possible experiments and tests to be performed since the specimens did not have to be preserved. Additionally, botanists could study plants in their natural habitats and view a range of species and environments that would not be available to them in Europe.[54] This also expanded the range of research available to European botanists, as it was easier for them to procure foreign research trips. Towards the end of the nineteenth century it became common for eager young botanists to spend at least some part of their education at field laboratories abroad.

Advances in microscope technology and new microscope methodologies also aided in the shifting view and practice of botany.[55] In the 1820s the compound microscope started manufacture in Europe.[56] These microscopes were highly sought after for their perceived clarity.[57] Fifty years later more improvements came to microscopy in the form of oil immersion

[53] Cittadino, *Nature as the Laboratory,* 2.

[54] Ibid.

[55] Ibid., 15.

[56] Ibid.

[57] Ibid.

lenses, improved staining techniques, and technical advances for thinner slicing of sections.[58] Hofmeister's influential study into the alternation of generations of plants could not have taken place without these advances in microscopy. As science historian Eugene Cittadino explains, scientists including Hofmeister approached the exploration of botanical life in a new way, conducting microscopic studies into various plant life cycles.[59] Hofmeister's book, *Vergleichende Untersuchungen*, was one of the many shifting studies of the mid-nineteenth century. Microscopes were considered such an integral component to botanical work botanist, Matthais Jakob Schleiden (1804-1881) stated in his textbook,

> He who expects to become a botanist or zoologist without using the microscope is, to say the least of him, as great a fool as he who wishes to study the heavens without a telescope. I will therefore say no more respecting the value of this instrument.[60]

All of these transformations in botanical science under categorized as New Botany. Scientists at the time were keenly aware of changes taking place and articles can be found in contemporary science journals lauding botany's exciting evolution. These changes elevated botany's status within the science community for its increased scientific complexity and move away from mainly an inventory practice. Botany began being viewed as a discipline with value to study in its own right. However, New Botany was not embraced uniformly across Europe. Some countries specialized in more modern forms of botany while others preferred and excelled at a more traditional practice of the science. This dichotomy was most stark between Germany and England.

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[58] Cittadino, *Nature as the Laboratory,* 16.

[59] Ibid., 12.

[60] Matthais Jakob Schleiden, *Principles of Scientific Botany*, trans. Edwin Lankester (London: Longman, Brown, Green & Logmans, 1849) 575.

New Botany, New Teaching

Not only were the concepts behind botanical science changing, but there was also a shift in how it was being taught. The post-secondary education system across Europe was changing swiftly in an attempt to keep up with the needs of contemporary scholars and students. During the nineteenth century universities were being built or expanded in urban centers across Europe and North America.[61] From 1850 to 1880, in Germany alone post-secondary enrollment doubled.[62] With the rise of the Victorian industrial class and an expansion of the post-secondary system, education was more affordable to many families. A wider set of interests resulted in a student body from a wider breadth of social classes. More young people were enrolled in post-secondary schooling, therefore demanding a more diverse education than ever before. Previously, a university education was mainly sought by members of the upper class for liberal arts education, focusing on ancient Greek and Latin and select professions like physicians and lawyers. Now, students were interested in learning about the advances in science and technology. Given these changes, established educational institutions began offering a wider breadth of courses and others were founded with a mission specifically to meet this growing need.

Along with the expansion of the educational networks came a change in the method of teaching science. As new buildings were being constructed, many institutions added laboratories. Traditionally, science classes were taught by lecture only, but with the rise of new methods as previously discussed a shift towards experimental or "practical" science laboratories was a necessity for any modern scientific educational program. An emphasis was placed on original

[61] Rothblatt, *The Modern University,* 350.

[62] Cittadino, *Nature as the Laboratory,* 9.

research and laboratory work.[63] New Botany teaching methods in particular stressed the importance of laboratory and fieldwork. Students were expected to learn by personal observation as well as by lecture.[64] Many hours were to be spent in the laboratory studying and dissecting specimens as well as in the field collecting and observing plants in their natural habitats. This created a need for botany students to learn laboratory techniques and have hands-on experience rather than learn solely via lecture. Prospective students therefore sought educational institutions that could deliver quality practical education.

During the nineteenth and into the twentieth century, one country stood out in its excellence in botanical research and education. Germany was unrivaled in its superiority of New Botany research, laboratories, and teaching.[65] New Botany research focused on physiological aspects of the science and this previously neglected component of botany was emphasized throughout German laboratories and universities. Germany became the hub for this particular version of the science due to the confluence of an expansion of the university system and several pioneering scientists inspired by Darwinism.[66] Among the pioneering New Botany scientists were Julius von Sachs (1832-1897), Hugo de Vries (1848-1935), and later, Eduard Strasburger (1844-1912).[67] These botanists were of the first generation that had received education that included Darwinian evolution. This cohort of scientists were supporters of evolution by natural

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[63] Richard A. Jarrell, "Science Education at the University of New Brunswick in the Nineteenth Century," *Acadiensis* 2, no. 2 (April 4, 1973) 55; Cittadino, *Nature as the Laboratory,* 1.

[64] Bower, "English and German Botany," 132.

[65] Morton, *History of Botanical Science.* 364.

[66] For further information on the reasons behind Germany's transformation into the modern botanical hub, see Cittadino's, *Nature as the Laboratory*.

[67] Strasburger wrote *Lehrbuch der Botanik für Hochschulen (Textbook for Botany)* in 1894 which revolutionized the way in which many scientists thought about botany.

selection but took a different approach to Darwin's work than even he had intended.[68] These scientists implemented the theory to examine plant adaptations to their environments, internal and external, rather than simply looking for physiological changes as other botanists of the period were.[69]

By the 1870s, English botanists were realizing that Germany offered a particular education that was available nowhere else and English students flocked to German universities.[70] Germany had been very successful in creating a system of well-regarded botanical schools. Most were founded by individuals and tied to universities with funding from the government and other supplementary sources. The first of these schools in Germany was established by Anton de Bary (1831-1888) at the University of Freiburg-im-Breisgau in 1858. In the next decade there were additional laboratories, with endowments, set up in Breslau, Munich, and Jena along with de Bary's enlarged laboratory in Halle.[71] Many others were soon to follow, and by the late nineteenth century any serious European or American botany student that could afford to was attempting to study at German botanical laboratories. The most popular were Julius Sach's University of Würzburg and de Bary's new laboratory at the University of Strasbourg.[72] Germany dominated the botanical education system internationally so that it was almost a requirement for any serious botany student to gain education there late in the century.[73]

[68] Cittadino, *Nature as the Laboratory,* 4.

[69] Ibid.

[70] Ibid., 24.

[71] Ibid., 15.

[72] Farlow, "The Change from the Old to the New Botany," 82; Cittadino, *Nature as the Laboratory,* 15-16.

[73] Farlow, "The Change from the Old to the New Botany," 84.

Although these botanical innovations were embraced in Germany the same was not so in England. English botany was much critiqued for being outdated. Sachs even commented, "the English still employed methods and principles developed by Robert Brown forty or fifty years ago."[74] This is a somewhat unfair characterization on Sachs' part. English botany was well respected in systematic and economic botany, however it remained steadfast in its loyalty to a more traditional form - many botanists continued to teach and research mainly taxonomy and classification.[75] England had a vast empire and its ability to enhance the economic viability of any plant species was of the utmost importance to English stakeholders.[76] Additionally, the study of botany in English schools was still considered largely a utilitarian exercise for physicians rather than a useful field in itself.

English scientists were concerned over the superiority of the German university system's science education. England itself had a fairly small university system with only three universities in 1826 - Cambridge, Oxford, and the University of London - while the smaller nearby country of Scotland had established five universities by that time.[77] The University of London was founded in an attempt to address issues of contemporary empire life and with the goal of being a more affordable and non-denominational alternative to Oxford or Cambridge. Another aim of modernization at the University of London was to offer courses in natural sciences, which were severely lacking in England.[78] The school met with much difficulty from traditionalist boards,

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[74] Cittadino, *Nature as the Laboratory,* 23.

[75] Zeller, *Inventing Canada*, 184. Traditional botanical practice consisted mainly of identifying and classifying plants and assessing their economic value.

[76] Ibid.

[77] Rothblatt, *The Modern University,* 349.

[78] Arthur Percival Newton, *The Universities and Educational Systems of the British Empire*, British Empire: A Survey No. 10 (London: W. Collins Sons & Co, Ltd, 1924) 19.

however, and struggled to receive its charter to offer degrees. Opposition to this new type of school centered around its lack of a religious test and the expansion of courses offered, including professional and science courses.[79] The school's proposed offerings were a vast difference from the traditional liberal arts education based in humanistic subjects, Latin, Greek, and math. Science education was generally omitted or given cursory attention in tradition English liberal arts schooling.[80] However, sentiment was growing within England to expand its science educational offerings as it was swiftly being surpassed by German schools.

Mason Science College was founded in 1875 to fill this educational gap. The school opened in 1880 with an address by “Darwin’s Bulldog,” Thomas Henry Huxley (1825-1895). Huxley spoke in metaphors of the battles that proponents of science education would have to fight against those who considered science education impractical or uncultured.[81] Although the University of London had offered some natural science courses, Mason Science College was unique in its focus on scientific education. Its main goal was to offer excellent scientific education for Birmingham area students, but as Huxley highlighted language and literature classes were not neglected. The school also offered English, French, and German courses to provide a well-rounded curriculum.[82] Mason Science College was hailed as a beacon of science education in England. However, it struggled to receive a charter, and thus its students were required to apply for their degrees through the University of London. Finally, in 1900, Mason

[79] James Jackson Walsh, “The University Movement in the North of England at the End of the Nineteenth Century,” *Northern History* 1, no. 46 (2013) 122. Religious tests were instated at some schools such as Oxford and Cambridge in England and Scotland as a requirement to obtain a degree. Religious tests were not wholly removed until the passing of the Religious Tests Act in 1871.

[80] Jarrell, “Science Education at the University of New Brunswick," 55-56.

[81] Thomas Henry Huxley, "Science and Culture." Opening of Mason Science College, Birmingham, England, 1880.

[82] Huxley, "Science and Culture."

Science College received royal charter and was renamed the University of Birmingham. Subsequently, it was able to grant degrees in its own right. The fight to prove the worth of science education at Mason Science College was difficult but eventually won and was trailblazing for other communities and institutions. Concern over modern scientific education was not unique to England, Canada was also struggling with how to offer quality science instruction.

Botanical Science in Canada

On the other side of the Atlantic Ocean, Canada, a dominion of England, was a quickly growing country where scientists were interested in the economic potential of the country's natural resources and the geographic distribution of native plants (Figure 1).[83] Throughout the century, Canadian botanists continued to concern themselves mostly with economic botanical research and an inventory of Canadian plants to investigate these questions.[84] After Confederation in 1867, the Canadian government attempted nation building, including an effort by the 1880s John A. MacDonald government for the nationwide professionalization of science.[85] Due to the government's loyalism and a slight anti-American sentiment, Canadian scientists generally preferred to distance themselves from their American colleagues and strengthen ties to British associations.[86] Canada was already behind its European counterparts in regard to the development of scientific and educational communities. However, developing a

[83] Zeller, *Inventing Canada*, 269-70.

[84] Zeller, *Inventing Canada*, 189.; Bovey, Henry T., "A Lecture on the Progress of Science in Canada" (Lecture, St. Paul's YMCA, Montreal, February 22, 1886) 7; Bower, "English and German Botany," 136.

[85] Vittorio M. G. de Vecchi, "The Dawning of a National Scientific Community in Canada, 1878-1896," *HSTC Bulletin: Journal of the History of Canadian Science, Technology and Medicine* 8, no. 1 (26) (1984) 50.

[86] de Vecchi, "A National Scientific Community in Canada," 50.

Figure 1. Map of the Dominion of Canada in 1900 from George Johnson, *Canada its History Productions and Natural Resources*. (Ottawa: Canada Dept. Agriculture, 1900). University of Manitoba Archives & Special Collections.

strong connection to the prestigious British scientific community and being a relatively young nation with a sparse population relegated Canadian scientists to a subordinate position.[87]

Attempts were made to develop intellectual societies throughout the country to help foster an educated elite. Most of these societies were regionally based and included a mixture of science, history, and literature. One of the first groups based on scientific discussion was the Natural History Society of Montreal, founded in 1827, whose goal was "the investigation of natural history of Canada."[88] It had a small museum, a scientific library, and published the journal, *Canadian Naturalist.* On a national scale, the Royal Society of Canada was founded in 1882 by the Governor General, the Marquis of Lorne to build a nationwide community. The Society was granted royal charter the following year and was favorably received by the government. Although the Royal Society was closely tied to the government, the federal government soon lost interest as it did not produce any concrete, utilitarian results.[89] With the lack of public and governmental support the Society was overshadowed by other organizations like the British Association for the Advancement of Science, which resulted in the weakening of the national Canadian science community. At the time, a majority of scientists were employed by the government and the Canadian university system had not yet developed a strong graduate infrastructure. These societies were where the scientific elite were to be found; they were the backbone of the Canadian scientific community.

Throughout the nineteenth century, the population within Canada grew and the lands under British control expanded, creating a need for a more complex educational system. Earlier

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[87] de Vecchi, "A National Scientific Community in Canada," 52.

[88] *Constitution and Bye-Laws of the Natural History Society of Montreal* (Montreal: Montreal Gazette, 1828), 1.

[89] de Vecchi, "A National Scientific Community in Canada," 41

post-secondary institutions existed in Canada, but neither could they grant degrees nor were they able offer education on par with universities in Europe. The first post-secondary institution in Canada was the Université Laval in Quebec City, which was established and funded by the Seminary of Quebec in 1663 and received its royal charter from Queen Victoria in 1852. The University of King's College was founded in Windsor, Nova Scotia by Anglican Loyalists in 1789 and was granted royal charter in 1802. King's College was the first institution to receive university status in Canada.[90] In the second half of the nineteenth century, the post-secondary infrastructure of Canada grew rapidly with schools receiving charters in each region of the Dominion. Although most of them were small, with an enrollment of less than 100 students, by the late nineteenth century there were approximately twenty universities in Canada.[91]

Early in their history, Canadian universities, such as Université Laval, were usually founded by religious organizations and staffed by clergy. Some of the clergy were formally educated in the topic areas that they taught but many of them were self-taught amateurs. Regardless of the scholastic background of these educators, they primarily approached their lectures through a religious lens.[92] With the modernization and secularization of scientific practice, this approach to scientific education became particularly old-fashioned. Canadian post-secondary institutions eventually began to modernize, but changes came slowly.

Canadian universities often followed the English model and offered science as a cultural subject.[93] Most schools offered courses in chemistry, geology, and natural philosophy. A few

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[90] King's College is now located in Halifax, Nova Scotia but it was originally established in Windsor, Nova Scotia. The school relocated to Halifax after a fire ravaged the Windsor campus in the 1920s.

[91] Henry E. Duckworth, *The University of Manitoba: An Illustrated History* (University of Manitoba Press, 2001) 3.

[92] J. T. H. Connor, "To Promote the Cause of Science: George Lawson and the Botanical Society of Canada, 1860-1863," *Scientia Canadensis* 10, no. 1 (1986) 4.

[93] Jarrell, "Science Education at the University of New Brunswick," 56.

schools also offered courses in natural history, however, these classes were considered part of a liberal arts education and not a science specific program. Botany was not introduced into Canadian universities until the 1850s.[94] Additionally, classes were taught in a traditional lecture style with little to no laboratory work.[95] Students did not receive the research-based laboratory education provided in Germany. In fact, it was not until the late nineteenth century that any Canadian universities were able to train research scientists.[96] At that time, they began hiring academically trained botanists who emphasized plant anatomy, physiology, and pathology to teach botany rather than interested amateurs and naturalists.[97] The transition from clergymen scientist to professional scientist teaching in universities was slow and lacked uniformity across the country. By 1900, the two biggest universities for scientific education were McGill University in Quebec and the University of Toronto in Ontario, which had dedicated science laboratories and over 1,000 students each.[98] McGill University staffed professors in chemistry and mineralogy, botany, physics, geology and paleontology, and zoology.[99] The University of Toronto had multiple professors each in physics, chemistry, biology, and mineralogy and chemistry.[100] Yet even for its large size, the University of Toronto was not necessarily cutting-edge, scientifically. For example, William Hincks (1794-1871), hired by the University as the agriculture professor, emphasized natural systems of classification, and his students found his

[94] Zeller, *Inventing Canada*, 206.

[95] Bovey, "The Progress of Science in Canada," 8; Jarrell, "Science Education at the University of New Brunswick," 56.

[96] Jarrell, "Science Education at the University of New Brunswick," 57.

[97] Zeller, *Inventing Canada*, 264-265.

[98] Jarrell, "Science Education at the University of New Brunswick," 76.

[99] Ibid.

[100] Ibid.

methods antiquated and “leaving much to be desired."[101] The University of Manitoba, around the turn of the century, was a much smaller school, but had established scientific education to a greater extent than institutions of larger size.[102]

Manitoba had become Canada’s fifth province just over three decades earlier in 1870. Winnipeg, Manitoba’s capital, was a small but swiftly growing city at the turn of the century that registered its first census with a population of 240 (Figure 2 and 3).[103] By 1900, the population had swelled to over 42,270, an increase of 17,512.5%, earning it the moniker of Mushroom City.[104] This influx of residents into Manitoba created a need for a more robust and complex infrastructure, which included a modern university. To expand the province’s educational offerings the provincial government granted charter to the University of Manitoba in 1877.[105]

The University of Manitoba was formed as a degree granting institution in the model of the University of London. Teaching of students was entrusted to the three colleges that formed the University: Manitoba College, St. Boniface College, and St. John’s College. Wesley College joined the affiliation a few years later in 1888. Each was run by separate religious orders that

[101] Zeller, *Inventing Canada*, 209.

[102] Jarrell, “Science Education at the University of New Brunswick," 76.

[103] Statistics Canada. *1870 Census of Manitoba.* Statistics Canada [database online]. Ottawa, ON, 2013. Available from: http://www.bac-lac.gc.ca/eng/census/1870/Pages/about-census.aspx. Indigenous peoples who lived in tents or did not have permanent homes were not counted in the census.

[104] Statistics Canada. *Census of Canada, 1901.* Statistics Canada [database online]. Ottawa, ON, 2016. Available from: http://www.bac-lac.gc.ca/eng/census/1901/Pages/about-census.aspx. "In 1901, the enumerators were not thorough in their work and many Aboriginal areas were not enumerated or only partially enumerated. In some cases, the people themselves refused to be enumerated."

[105] Women were not allowed to attend the university until 1888.

Figure 2. Postcard showing Main St., Winnipeg, MB, 1908. UMA, Meltzer fonds, Box 3, No. 675

Figure 3. Valentine & Sons of Dundee, Postcard showing Portage Ave., Winnipeg, MB, c. 1909. UMA, Meltzer fonds, Box 3, No. 492.

quickly outgrown and there was a call for the University to begin its own teaching, particularly in the sciences. The three colleges had varying qualities of science education as classes were mainly taught by clergymen scientists. An 1894 graduate commented, "…we had a little of everything and not much of anything. The age of the specialist had not yet arrived in Manitoba and I am inclined to suspect that the professor was sometimes only a day ahead of us in the subject he was teaching…"[106] After much debate between the three colleges, it was finally agreed that the University of Manitoba would undertake its own teaching of sciences. This decision was reached in part after urging from the Medical College, which had been founded in 1883, complained of a lack of proper science training for its students.[107] However, the University possessed no buildings, staff, or funding for the required changes.

Work soon began to build facilities to accommodate modern scientific education, and in 1901 the University finalized construction on its first building which was devoted entirely to science classes (Figure 4). Due to the fact that the University had not yet fundraised enough to attract adequately trained science professors, the previous College staff remained teaching in this new building. In 1904, after years bureaucratic struggle the University of Manitoba had hired its first six professors, all of whom taught science (Figure 5).[108] The new professors Matthew A. Parker (Head of Chemistry), Gordon Bell (Head of Bacteriology), A.H.R. Buller (Head of Botany and Geology), Frank Allen (Head of Physics and Mineralogy), Swale Vincent (Head of Physiology), and R.R. Cochrane (Head of Mathematics), quickly developed their respective departments and began teaching in the 1904-1905 school year.

Prior to 1900, Canada struggled as a young nation trying to develop its own science

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[106] Charles Camsell, *Son of the North*, Ryerson Paperbacks, No. 9 (Toronto: Ryerson Press, 1966) 30-31.

[107] Morton, "The Founding of the University of Manitoba," 9.

[108] Duckworth and Goldsborough, "Science Comes to Manitoba," 5-6.

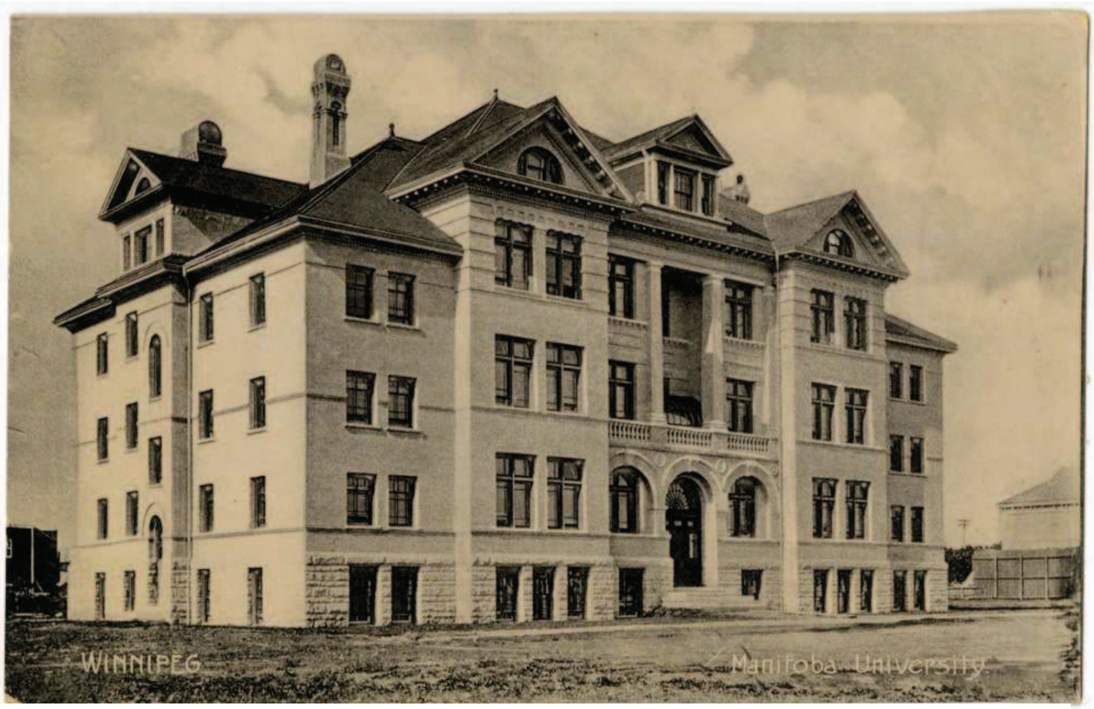

Figure 4. W.G. MacFarlane, Science Building, University of Manitoba Broadway campus, c. 1905. UMA, Meltzer fonds, Box 1, No. 119.

Figure 5. "Original 6" University professors, Gordon Bell, Frank Allen, Swale Vincent, Matthew Parker, A.H. Reginald Buller, and R.R. Cochrane, 1904. UMA, Buller fonds, PC 175 (A.07-62), Box 22.

community and network of post-secondary institutions on par with European institutions - with a fraction of the infrastructure in place. Canadians attempted to use models of British institutions, like the British Association for the Advancement of Science, but these models broke down or were overshadowed by their more prestigious predecessors. This is also true for the building of a scientific community. The Canadian government was dedicated to utilitarian applications of science and less obviously practical research was not important and therefore not funded. This left a gap in the scientific community, particularly since there was no established post-secondary network to fill other research areas. As universities were built and staffed with academically trained professors, a number of individuals stood out to help foster a uniquely Canadian scientific community and bring modern science to a country that had embraced more traditional forms.

Chapter 2: Reginald Buller in Manitoba

Manitoba was a young and prosperous province in the early twentieth century but it was experiencing growing pains in the development of its science community. By 1900 the province had consolidated post-secondary education within the University of Manitoba. The University had expanded its role to include science teaching and a new building had been constructed.[109] However, science education in the province remained limited and antiquated. This chapter will show how a new and more modern method of botany training and practice was transferred to the Canadian prairies through a young professor, Dr. Buller, and how this movement of knowledge helped put Winnipeg, Manitoba at the forefront of Canadian botanical research in the early twentieth century.

The Buller family history and an in-depth biography of Buller has been researched by Gordon Goldsborough in a 2004 article. I will provide a brief overview of the family's history here. The Buller family were tenant farmers since the 1600s.[110] Alban Gardner Buller was the first in the family to obtain post-secondary education, earning a law degree.[111] He married Mary Jane Huggins in the late 1860s and the two moved to Mosley, England where Alban held positions as a barrister, magistrate, and city councilor.[112] Mary and Alban Buller had seven children of which Arthur Henry Reginald Buller was the fifth child, born in August 1874.[113]

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[109] This building, often referred to as the Science Building, was the only University owned structure and was located on Broadway across from the Legislative Building on what is now Memorial Park. Other buildings were added to the site on an as-needed basis until the campus was abandoned.

[110] Goldsborough, "Reginald Buller," 17.

[111] Ibid.

[112] Ibid.

[113] Ibid.

Reginald was educated at a boarding school in nearby Birmingham.[114] His interest in natural history developed later while he attended Queen's College, Tauton.[115] He transferred to Mason Science College, a University of London affiliate, at the age of 18 to pursue further studies in botany. Reginald took his examinations from the University of London and received his Bachelor's of Science degree in 1896.

Buller flourished at Mason Science College, being awarded the Helsop Gold Medal and upon graduation he received a Science Research Fellowship from the Royal Commission for the Exhibition of 1851. At Mason Science College, he studied under William Hillhouse (1850-1910). Hillhouse was a prominent English New Botanist who was a student of Strasburger and aided Strasburger with the translation of his *Handbook of Practical Botany*. It was at Mason Science College that Buller was likely introduced to the modern scientific methods and thinkers of the day, such as Hugo de Vries, Julius von Sachs, and Ernst Haeckel. The Science Research Fellowship allowed Buller to pursue three years of scientific research. As an aspiring and talented young botanist, Buller chose to travel to Germany, the center of New Botany research in 1897. From 1897 to 1899 he studied at Leipzig University under the supervision of Wilhelm Pfeffer (1845-1920) researching fern reproduction (Figure 6). While in Leipzig, Buller earned his PhD with his dissertation, "Die Wirkung von Bakterien auf tote Zellen (The Effect of Bacteria on Dead Cells)."[116] The following year he moved to Munich to study at the Forstbotanisches Institute with Robert Hartig (1839-1901), a renowned forest pathologist until 1901. Buller followed the model of other keen young scientists and traveled abroad for scientific research. During the spring of 1900 and 1901 Buller worked at the British Association table at the

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[114] Goldsborough, "Reginald Buller," 17.

[115] Ibid.

[116] Brooks, "Arthur Henry Reginald Buller, 1874-1944," 51.

Figure 6. Buller and classmates outside of the Botanic Institute, Leipzig, 1899. UMA, Buller fonds, PC 175 (A.07-62), Box 15.

Stazione Zoologica, in Naples, Italy, a private research station founded by Anton Dohrn (1840-1909) and founded on the principles of Darwinian evolution.[117] While at the Station Zoologica Buller worked outside of his field and studied the fertilization of sea urchin eggs. However, this experience was invaluable as the Stazione Zoologica was one of the most respected biological research institutes in the world and at the height of technological advances. Buller's experiences and training at Leipzig University, the Forstbotanisches Institute, and the Station Zoologica had a significant effect on his future teaching style and methodologies.

All four of these institutions had robust New Botany ties and Buller was significantly impacted by his time abroad. Following his post-graduate work, Dr. Buller returned to the University of Birmingham, formerly Mason Science College, as an assistant lecturer of botany and earned his Doctorate of Science. While at the University of Birmingham in 1903, Buller tested some of his new pedagogical techniques by offering a series of 20 lectures, including laboratory exercises on plant diseases.[118] It was only the second time plant pathology had been taught in England and the series was met with great acclaim.[119] Buller's successful lectures series was possibly a reason he was offered a special lectureship in plant pathology at the University of Birmingham. However, he refused this position in lieu of accepting the post of Professor of Botany and Geology at the University of Manitoba.[120] Although it has not been highlighted in the literature, Buller played a significant role in the transition from theological education to a science-led university.

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[117] Brooks, "Arthur Henry Reginald Buller, 1874-1944," 51; Anton Dohrn, "The Foundation of Zoological Stations," *Nature* 5 (1872) 279-80.

[118] Estey, "A. H. R. Buller: Pioneer Leader in Plant Pathology," 17.

[119] G. C. Ainsworth, *Introduction to the History of Plant Pathology* (Cambridge; New York, NY: Cambridge University Press, 1981) 224.

[120] Goldsborough, "Reginald Buller," 18.

Moving halfway across the world to a relatively new country for a job seemed dramatic however there are several reasons in favor of Buller's decision. First, Buller's position at the University of Birmingham paid approximately £150 per year, whereas his starting salary at the University of Manitoba was $2,500.[121] Additionally, upward mobility was low at an institution like the University of Birmingham. Moving up in the institutional hierarchy was unlikely and it would have taken a long time, if possible. At the University of Manitoba, he instantly started out as a professor and the head of two departments. Also, the University of Manitoba offered a long summer break of almost five months from April to September which would allow Buller ample time to travel and conduct research.[122] This was a longer break than other universities therefore Buller would be unlikely to get such an offer again. Finally, in Winnipeg, Buller would be helping to build a scientific community and university where little existed, as opposed to Birmingham which was far more established. This is a highly unique opportunity and allowed Buller to instantly be one of the scientific authorities of the community.

Prior to the late-1800s, post-secondary education in Manitoba was almost exclusively controlled by clergy. After some discussion between the three English colleges, a committee was appointed for teaching natural science, with an instructor from each school.[123] Two of the three instructors were not clergy, St. John's Colleges, Edgar B. Kenrick and Wesley College's, George J. Laird. However only Laird was scientifically trained as he had received his PhD from the University of Breslau in crystallography.[124] These instructors were set aside when the University

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[121] Goldsborough, "Reginald Buller," 18. Buller's exact wage at the University of Birmingham is not known, but his replacement was paid a yearly salary of £150, which was in the usual range of £150 to £175.

[122] Letter from A.H.R. Buller to Elsie Wakefield, 6 March 1911, MSS 184 A.04-25, Box 5, Folder 2, A.H. Reginald Buller fonds, UMA, University of Manitoba.

[123] Duckworth and Goldsborough, "Science Comes to Manitoba," 4.

[124] Ibid.

decided to take a different approach to science education, opting to hire new academically trained research scientists for all of their scientific topics in 1904.

Buller promptly took up his mantle of scientific expert within the community. In 1904, the University of Manitoba hired six academically trained scientists to direct science education at the university. The transition did not go entirely smoothly. In December 1904, Buller and Reverend Lewis Drummond (1848-1929) engaged in a dispute within the editorial section of the *Manitoba Free Press* over evolution. In a sermon published in the *Manitoba Free Press Bulletin* Drummond refuted evolution stating, "Men who pretended to great learning had given to the world the theory of evolution…"[125] He went on to claim that it is impossible for humans and the "lower order of animals" to have common ancestors.[126] Buller responded in the *Manitoba Free Press* the following week:

> [I] hope that he will in no way consider this letter to be a personal attack or one directed in any special manner against the Catholic creed. In the interests of truth and as one of the liege men of Natural science I have but counted it my duty to utter a protest against statements which I feel convinced, are misleading and therefore inimical to the welfare of the community.[127]

Drummond replied that he welcomed the opportunity to more fully explain his position since the column represented no more "…than a small fraction of what [he] said on the subject…"[128] Drummond did ask that Buller responded to his column in next week's paper but there's no evidence of a response.[129] It is possible that Buller considered his purpose fulfilled. Alternatively, Buller could have heeded the warning he received from former instructor, Edgar

[125] A. H. Reginald Buller, "Evolution and Christianity," *Manitoba Free Press*, December 10, 1904.

[126] Ibid.

[127] Ibid.

[128] Lewis Drummond, "Evolution and Christianity," *Manitoba Free Press*, December 19, 1904.

[129] Ibid.

Kenrick who claimed that it was because of Drummond that he lost his position.[130] The climate in Manitoba was already tense between religious and secular education plus Rev. Drummond was on Buller's hiring committee and the University of Manitoba council. Religious educational institutions were hesitant to hand over science education to secular instructors and this interaction would not have put administrators' minds at ease.

Buller was a staunch proponent of Darwinian evolution, but he also supported eugenics, believed in telepathy, and was somewhat religious.[131] This set of opinions would be contradictory by modern standards but were somewhat common during his time. Although some of the discussion surrounding religion and evolution had died down, there was still debate between the two worldviews.[132] As science historian, Peter Bowler states, scientists developed different mechanisms for dealing with science and religion: "conflict, cooperation, and coexistence" and that each model was in use in the early twentieth century.[133] Not much is known about Buller's religious views as he did not discuss them frequently. Buller appears to have occupied a median space, in a letter from 1910 he writes:

> "…the truest religion is not bound up with any definite historical records like those of the Bible and my best friends have given up the belief in the supernatural parts of Christianity. In my own struggle for freedom several well-meaning but misguided person did their best to cloud my judgement and caused me a good deal of suffering – but that is past. I simply changed my wings: the first pair were too small and imperfect for my growing mind…"[134]

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[130] Goldsborough, "Reginald Buller," 20.

[131] Buller had ten of Charles Darwin's books in his library and a bust of him in his office.

[132] Peter J. Bowler, *Reconciling Science and Religion: The Debate in Early-Twentieth-Century Britain* (Chicago: University of Chicago Press, 2014), 2.

[133] Bowler, *Reconciling Religion and Science*, 8.

[134] Letter from A.H.R. Buller to Katherine M. Wright, 10 January 1910, Box 2, Folder "Earliest letters from a case in private room 1909 etc.," Library and Archives Canada, in Goldsborough, "Reginald Buller," 20-1. This letter is now in the University of Manitoba Archives' collections.

Buller occasionally attended church, although mostly to listen to the choir, but he had at least seven Bibles in his book collection.[135] Additionally, Buller's brother-in-law was a clergyman and he occasionally sketched churches and religious figures.[136] However, what seemed most important to Buller was that science be practiced and disseminated properly. Buller's public debate with Drummond was not the last of such episodes. At a Wesley College fundraiser, a 1916 *Manitoba Free Press* article reported that professor Eber Crummy commented:

> Education was fundamentally defective unless intimately associated with religion. Education aimed at the formation of the highest type of personality and character through the development of the highest spirit. But this was impossible except where the religious atmosphere and purpose pervaded the whole process. …a Christian professor would be installed to teach any subject and to conduct any course if it was found that such subjects or courses were conducted in other colleges by professors who flaunted their infidelity or skepticism. Dr. Crummy ridiculed the idea that infidelity was a strength to science..[137]

Buller did not appreciate the threat of religious oversight within the College responding:

> How fortunate it is for the University of Manitoba that Rev. Dr. Crummy is not in charge, for if he were, the system of electing professors and instructors, which has how been in vogue for many years, would be at once changed. There would be a reversion to the methods of the Inquisition. Men, however honorable and able, would be penalized for holding religious opinions differing from those of their president.[138]

Buller wanted to impart unto the clergy in Winnipeg that he felt strongly that "…are not at liberty to talk at random on scientific subjects."[139]

Seemingly at odds with Buller's staunch belief in modern science, Buller also believed in eugenics and telepathy. These ideas however were fairly common among scientists and other

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[135] Estey, "A. H. R. Buller: Pioneer Leader in Plant Pathology," 21; Johnson, *Catalogue of the Buller Memorial Library*, 65.

[136] Goldsborough, "Reginald Buller," 21.

[137] "Campaign in Aid of Wesley College," Manitoba Free Press, January 24, 1916.

[138] A.H. Reginald Buller, "Freedom of Thought," Manitoba Free Press, January 26, 1916, sec. Editorial.

[139] Letter from A.H. Reginald Buller to Edgar Kenrick, 11 December 1904, Buller scrapbook, Buller Memorial Library in Goldsborough, "Reginald Buller," 20. This scrapbook is now in the University of Manitoba Archives' collections.

intellectuals around the turn of the century. Eugenics in particular had ties to early geneticists and Darwinists and was a cause widely taken up among the professional middle class and the political right.[140] Buller had multiple books on eugenics and heredity, including two by Darwin's cousin and famed eugenicist, Francis Galton.[141] Additionally, he promoted eugenics principles in talks and newspapers stating, "No animal or plant breeder would breed from his worst stock. Why should humanity be so foolish to allow feeble-minded and other congenitally defective people to be set free from an institution unsterilized and free to burden the next generation with defectives like themselves?"[142] Buller was also a firm believer of telepathy commenting in a University address, "In my opinion, Telepathy by means of overwhelming evidence has been established as a fact."[143] Buller conducted eight telepathic experiments with two of his friends, Mrs. Hawkes and Ruth Cohen.[144] Although all of his experiments were failures, Buller was positive that Cohen had telepathic abilities, even if they were only spontaneous.[145] Buller's contemporary Dr. T.G. Hamilton (1873-1935), a respected medical doctor, became quite famous during the 1920s for testing mediums and scientific séances held in Winnipeg. Like Buller, Hamilton believed in telepathy. Modern readers may see these beliefs as unorthodox, it was not so for Buller and his contemporaries.[146] He had uncompromising faith in modern science based

[140] Peter J. Bowler, *Evolution: The History of an Idea*, 25th anniversary ed. (Berkeley; London: University of California Press, 2009), 310.

[141] Johnson, *Catalogue of the Buller Memorial Library*, 31-2.

[142] A. H. Reginald Buller, “The Case for Sterilization,” Winnipeg Free Press, February 6, 1935.

[143] A. H. Reginald Buller, *The Progress of Science: An Opening Address for the University of Manitoba* (Winnipeg, MB: University of Manitoba, 1912) 28, Text-fiche FC16 C105 CIHN No. 84231

[144] Letter from A.H.R. Buller to Mrs. Hawkes, 20 October, 1913(?), MSS 184 A.04-25, Box 1, Folder 8, A.H. Reginald Buller fonds, UMA, University of Manitoba.

[145] Ibid.

[146] Egil Asprem, *The Problem of Disenchantment: Scientific Naturalism and Esoteric Discourse 1900-1939*, Numen Book Series (Leiden: Brill, 2014) 290-1.

on the scientific method and faced these concepts with what he considered a logical and systematic approach.

Buller at the University of Manitoba

Upon arriving in Winnipeg in 1904 Buller and his colleague Swale Vincent were brought to the Metropolitan Hotel.[147] The Metropolitan was once the home of St. Mary's Academy for Girls and the Winnipeg College for Music and it was one of the few hotels befitting men of Buller's and Vincent's status available in the city at the time.[148] In the late nineteenth and early twentieth century Winnipeg's population included a high percentage of young, unmarried men.[149] Winnipeg's well-known "hotel row" along Main Street housed over 60 hotels, catering to these men offering alcohol, gambling, and prostitutes.[150] However, the concentration of hotels and businesses created a commercial center while still maintaining a large residential area.[151] This created a walking community for those living in the downtown core, which was an advantage to Buller who never owned a car.[152] After the first year, Buller moved to the Vendome Hotel for seven years before settling into the McLaren Hotel in 1913 (Figure 7).[153] Buller would reside in the McLaren for twenty-eight years, except for a one year hiatus in 1915.[154] The McLaren Hotel

[147] Goldsborough, "Reginald Buller," 19.

[148] Ibid.

[149] Alan F. J. Artibise, *Winnipeg: A Social History of Urban Growth, 1874-1914* (Montreal, OQ: McGill-Queen's University Press, 1975) 14. For more information on Winnipeg's history in the early twentieth century see Jim Blanchard's *Winnipeg 1912: A Diary* and Artibise's *Winnipeg: A Social History of Urban Growth, 1874-1914.*

[150] Artibise, *Winnipeg,* 154.

[151] Ibid.

[152] Ibid.; Estey, "A. H. R. Buller: Pioneer Leader in Plant Pathology," 23.

[153] Goldsborough, "Reginald Buller," 19.

[154] Ibid.

was built in 1910 as a grand 165 room hotel located on Main Street and Rupert Avenue. Buller appreciated the hotel's "excellent" billiards tables as the game was one of his favorite hobbies. Buller remained at the McLaren for the rest of his life, even after the hotel's reputation had diminished.

It may seem odd that he never purchased a home in Winnipeg, however, this arrangement was practical and convenient for Buller. Buller remained unmarried throughout his life and therefore he did not require a larger living quarters for a family. Consequently, Buller's effective home was his University office which he put more effort into decorating and where he kept his extensive library.[155] Without having to concern himself with the upkeep of a property, Buller could return to England for the long summer breaks to visit family, friends, and colleagues, and to conduct research at the Royal Botanic Gardens, Kew, or the University of Birmingham where he often had a laboratory space (Figure 8).

Research was a very important component to Buller's identity as a scientist. At the time of his appointment to the University of Manitoba, Buller was one of only a few of botanists that was the head of a 'pure' botany department, rather than an applied botanical program in Canada.[156] Although the University of Manitoba was one of the smaller and newer universities in the country, it placed a greater importance on science than larger liberal arts universities, such as the University of Toronto and McGill University.[157] However, the new university did not put emphasis on research by its professors. Buller and the other newly appointed staff were interested in pursuing their own research interests as well as teaching although this was

[155] Buller's attachment to his office did cause problems after his retirement when the University administration asked him to vacate the space. Buller took this request as a slight after years of service to the University, particularly since his office was much more like a home.

[156] Zeller, *Inventing Canada*, 206-207.

[157] Jarrell, "Science Education at the University of New Brunswick," 76.

Figure 7. McLaren Hotel, c. 1920.
UMA, Meltzer fonds, Box 3, No. 567.

Figure 8. Buller at Kew Herbarium, n.d.
UMA, Buller fonds, PC 175 (A.07-62), Box 15, Folder Buller on board SS Lapland...

discouraged by the University administration. In 1905, the six University of Manitoba science professors founded the Scientific Club of Winnipeg to "discuss new and current scientific questions and it is hoped that such discussion would act as a stimulus to original research on the part of its members."[158] In his first couple years in Winnipeg Buller regretted that he could not devote more time to his own research.[159] To make up for his lack of time during the academic year, he devoted his summers to research and publishing, and had four articles in the press by the end of his second year in Winnipeg.[160]

Public outreach was another of Buller's personal goals. Buller's preferred method of community engagement was through public lecture. He offered many lectures over his career but tended to demure from popular articles. Buller began in Winnipeg by initiating a public lecture series in February 1907.[161] As Goldsborough and Duckworth have shown, these lectures were very well received with good attendance and near the end of 1911 the lecture series was expanded into rural Manitoba.[162] He also gave lectures around the city at the Winnipeg People's Forum and the Grand Theatre, among others, all illustrated with his hand-colored magic lantern slides.[163] On Saturday mornings Buller would go to farmer's markets to lecture.[164] To further

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[158] Letter from A.H. Reginald Buller, Allen Parker, and Swale Vincent, 17 October 1905 as reproduced in F. D. White and A. D Robinson, *The History of the Scientific Club of Winnipeg, 1905-1965*, [3rd ed.]. (Winnipeg: The Scientific Club of Winnipeg, 1966) 5.

[159] Buller, "Report on the Botanical and Geological Departments 1904-1905," 9.; A. H. Reginald Buller, "Botanical and Geological Departments," in *Report of the Faculty of Science to the University of Manitoba, 1905-1906* (Winnipeg, MB: University of Manitoba, 1906) 10.

[160] Letter from A.H.R. Buller, Matthew A. Parker, and Swale Vincent, 17 October 1905 in F. D. White and A. D Robinson, *The History of the Scientific Club of Winnipeg, 1905-1965*, [3rd ed.]. (Winnipeg: The Scientific Club of Winnipeg, 1966), 5.

[161] Duckworth and Goldsborough, "Science Comes to Manitoba," 10.

[162] Ibid.

[163] Goldsborough, "Reginald Buller," 23.

[164] Nicholas P. Money, *Mr. Bloomfield's Orchard: The Mysterious World of Mushrooms, Molds, and Mycologists* (New York, N.Y.: Oxford University Press, 2002) 89.

expand his outreach Buller also utilized the train as a venue for his lectures, taking the train across Manitoba and Saskatchewan and giving talks at stations along the way.[165] Buller tailored his lectures to his audience and most of his lectures focused on agricultural topics. Some also centered on popular scientific topics of the day like evolution and the movement of land masses.[166] Buller was well known for his excellent lecturing abilities and his style captivated public audiences.

Part of the reason for these public lectures was to be a spokesperson for the University and to gain public support for the institution. The chancellor of the University of Manitoba, Archbishop Robert Machray died in 1904 and a new Chancellor was not appointed until 1908. Additionally, there was no University President hired until 1913. There was a University council which consisted of 58 members but Buller saw this group as actually, "controlled by a small number whose chief interest does not lie in [the University's] true progress, but to that of the affiliated denominational colleges."[167] With the fluctuation in leadership at the University and their role as educated elite in the booming prairie town, the new science professors took it upon themselves to be the representatives and advocates of the University. Very soon after his arrival, Buller was making public appeals on the behalf of the University, describing the inadequacy of the nearly new building and the need for an expansion of teaching and support staff.[168]

It was apparent from the first years with the new science teaching staff that there was a drastic change at the University. From the first two "Report of the Faculty of Science" all six professors were unanimous in their desire to remove the joint chairs, hire assistants, and add a

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[165] Goldsborough, "Reginald Buller," 23.

[166] Ibid.

[167] "Urgent Need of the University," *Manitoba Free Press*, January 6, 1908.

[168] Ibid.

research library.[169] In the botany and geology departments, Buller's first task was to outfit the teaching laboratories and lectures halls. To quickly prepare for the upcoming academic year, Buller spent $748.05 on "scientific apparatuses" including "botanical models, diagrams, physiological apparatus, glassware, and general laboratory supplies."[170] He noted that he wished to make considerable additions to these supplies in the following year but that the lecture theater was sufficiently outfitted.[171]

Buller was also emphatic about the lack of a library calling it, "…one of the greatest disadvantages under which the departments in [his] charge suffer."[172] The next year a library council was set up and an annual library grant was instituted.[173] The surviving books from the Alexander Kennedy Isbister (1822-1883) collection were transferred to the University of Manitoba and professor Frank Allen (1874-1965) secured a gift of books from Smithsonian Institute.[174] Initially, Frank Allen oversaw the library until a librarian, Florence Thompson (1865-1915) was hired in 1907.[175] By 1908, 5,000 books and periodicals had been acquired by

[169] R. R. Cochrane and Matthew A. Parker, "Report of the Faculty of Science 1904-1905," in *Report of the Faculty of Science to the University of Manitoba* (Winnipeg, MB: University of Manitoba, 1905), 3; R. R. Cochrane and Matthew A. Parker, "Report of the Faculty of Science, 1905-1906," in *Report of the Faculty of Science to the University of Manitoba* (Winnipeg, MB: University of Manitoba, 1906), 3.

[170] Cochrane and Parker, "Report of the Faculty of Science 1904-1905," 1; Buller, "Report on the Botanical and Geological Departments 1904-1905," 8.

[171] Buller, "Report on the Botanical and Geological Departments 1904-1905," 8.

[172] Ibid.

[173] William Lewis Morton, *One University: A History of the University of Manitoba, 1887-1952* (Toronto: McClelland & Stewart, 1957) 68.

[174] Cochrane and Parker, "Report of the Faculty of Science 1904-1905," 3. Alexander Kennedy Isbister left his library of almost 5,000 books to the University but much of the bequest was destroyed in an 1898 fire.

[175] Duckworth and Goldsborough, "Science Comes to Manitoba," 14. Florence Thompson was the wife of the chief customs inspector in Winnipeg but on top of her library duties she aided Swale Vincent in research and even co-published an article with him.

the library.[176] After Buller had arranged for the British Association for the Advancement of Science (BAAS) to have its 1909 meeting in Winnipeg, its members also began donating books to the University's library. The school received over 650 donated books right away with the promise for Buller's list of desired books to be circulated among members.[177] The growing library lead to a more rigorous courses for the science students and to the approval for a pharmacology program.[178] The University's small library was finally growing thanks to the hard work of the new science professors.

The original University of Manitoba building, which housed the science classes, was built on 6.6 acres on Broadway across from the Legislature provided by a land grant from the Province of Manitoba. Although the science building was almost new, there were space and equipment issues. Buller commented that he could not bring his first year botany class to the laboratory for "practical work" because there were not enough tables and chairs to accommodate the 54 students.[179] The building was designed by architect George Browne (1852-1919) who had also designed Wesley College in 1895.[180] Browne was assisted by George Bryce (1844-1931), the founder of Manitoba College and the chairman of the University's Building Committee. The school had a 120 by 70 foot footprint and was three stories plus a basement. The main floor included two large lecture theaters for physics and chemistry that each sat 150 students, two chemistry laboratories, a mineralogy laboratory, a physics laboratory, offices and storage rooms. The second floor housed the geology, zoology, and botany classrooms, a greenhouse, a library,

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[176] Morton, *One University*, 68.

[177] Goldsborough, "Reginald Buller," 23.

[178] Morton, *One University*, 68.

[179] Buller, "Report on the Botanical and Geological Departments 1904-1905," 9.

[180] Browne worked on a number of projects in Winnipeg, Montreal, and New. Browne had partnered with Samuel Frank Peters to work on Wesley College building.

Figure 9. One of Buller's botany classes, ca. 1920. UMA, courtesy Gordon Goldsborough.

Figure 10. Frederick W. Parkin, Laboratory, c. 1901-1908, UMA, University Relations and Information Office fonds (PC 80, A.83-52), Box 13, Folder 509, No. 3

and a 100 person capacity lecture theater. The third floor housed an assembly room and was intended for a museum. The basement had six chemistry rooms, a store room for bikes, and the caretaker's residence (Figures 9 and 10).[181] The botany department was outfitted by Buller over his tenure and included a lecture theater, a plant physiology laboratory, a plant morphology laboratory, the greenhouse, a darkroom for photography, the department head's office, and a mycology museum with specimens mostly collected by Buller.[182] Construction on the University of Manitoba building was completed in 1900. The building was opened by the Duke and Duchess of Cornwall and York at a grand ceremony on September 26, 1901.[183]

Enrollment grew quickly, in 1900 the University had only 243 students but by 1910 there were 726.[184] With the professors already voicing concerns about space limitations, it was clear a solution was needed. By 1909 the University Council approved the construction of the "Arts Building," to be erected near the existing University of Manitoba building on Broadway.[185] Still requiring more space, the University began renting space in nearby houses on Vaughan Street.[186] In 1912 the Province allocated more funds for an expansion of University buildings.[187] In 1915 the Manitoba government allowed the university temporary use of several buildings, including a succeeded in offloading his Geology chair by hiring Robert Wallace. Therefore, he could devote all of his time to his primary interest, botany. In 1901 the courses required for graduation were

[181] Goldsborough, "Reginald Buller," 22.

[182] The plant pathology museum was dismantled in 1910 to make office space for Robert Wallace, the new Head of Geology and Mineralogy.

[183] This was the future George V and Queen Mary.

[184] Morton, *One University*, 56.

[185] Richard A. Johnson, "The Broadway Site of the University of Manitoba: Origins and Demise," *Manitoba History*, no. No. 51 (February 2006) 22.

[186] Johnson, "The Broadway Site," 23.

[187] Duckworth, *The University of Manitoba,* 28.

altered from a primarily classics based curriculum to one that included English, history, math, Latin, and two of either Greek, French, German, or elementary science.[188] In 1903 these requirements were altered once again to limit the number of history classes and increase the natural science courses needed for a degree. Buller taught both junior (basic) and senior (advanced) botany courses. After the 1905-1906 academic year, the teaching load for the junior botany classes increased dramatically as medical students were thereafter required to take botany for their degree.[189] Around 1910, Buller was teaching 85 students in his junior classes and 12 in his advanced classes. This teaching load was compounded by the fact that none of the laboratories would accommodate the number of students that attended class and Buller opened multiple rooms at the same time, having to switch between them along with Charles Lowe.[190]

Buller persevered over the numerous obstacles facing him at the newly-formed and ill-organized university. He was an extremely popular professor well known for his captivating lectures. Students remember him as a performer, showing off in front of the classroom by making jokes or other minor theatrics. He was also very passionate about his topic area with a strong desire to impart scientific knowledge upon anyone who would listen. These two qualities combined to make Buller an internationally renowned lecturer over the course of his career. He developed a reputation as a respected expert in his field and was regularly asked to lecture in Canada, the United States, and England.[191] Through his teaching, Buller brought modern botanical education to Manitoba and helped develop a scientific community in Winnipeg.

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[188] Morton, *One University*, 54.

[189] Buller, "Botanical and Geological Departments," 9.

[190] A. H. Reginald Buller, "Department of Botany," in *Report of the President of the University to the Board of Governors, 1917-1918* (Winnipeg, MB: University of Manitoba, 1918) 44.

[191] Estey, "A. H. R. Buller: Pioneer Leader in Plant Pathology," 22.

Buller's Role in Canada and Abroad

Buller was well-known in Manitoba for his position as a botany professor and as an outspoken proponent for the University. He was active in the community, frequently giving lectures and coordinating with the government to address issues facing farmers in the province. Buller played a significant role in the building of Manitoba's scientific community and modern post-secondary scientific education. Buller became more prominent across Canada and internationally as his career progressed. He worked tirelessly to create a center of scientific research in Winnipeg and succeeded to a degree, however Manitoba remained somewhat isolated despite Buller's efforts.[192] Possibly because of his isolation in the "Wild West" or his revolutionary research on fungi, Buller did not receive the same level of recognition as some of his Eastern counterparts.[193]

Considering himself a man of science, Buller felt it was important to be involved in the larger scientific community. Consequently, he was a member of a plethora of scientific, botanical, and mycological organizations across North America and Europe such as the BAAS, the British Mycological Society, and the American Phytopathological Society, on top of helping found the Scientific Club of Winnipeg. He was also the first Western Canadian to be elected a Fellow of the Royal Society of London. Through these organizations he also advanced his profile and also held positions on several societies' executives. He was the treasurer of the Scientific Club of Winnipeg from 1907 to 1909, in addition to being a founding member. He was also elected president of all of the following associations, the British Mycological Society in 1913, The Royal Society of Canada in 1914-1915 and 1927-1928, the Canadian Phytopathological

[192] P. H. Gregory, "The Fungal Mycelium: An Historical Perspective," in *The Ecology and Physiology of the Fungal Mycelium*, ed. D. H. Jennings and A. D. M. Rayner, British Mycological Society Symposium 8 (Cambridge; New York: Cambridge University Press, 1984) 10.

[193] Gregory, "The Fungal Mycelium," 10.

Society in 1920, American Botanical Society in 1921, the Botanical Society of America in 1928, the Mycology and Bacteriology Section for the Sixth International Botanical Congress in Amsterdam in 1935. Buller was active in the international scientific community, regularly promoting his research.

As part of his efforts to remain connected internationally, Buller kept up extensive correspondence. His archives at the University of Manitoba contains 16 boxes of letters which Buller kept over the course of his career. Most of these letters are from scientific colleagues across Canada, England, the United States, and Germany and largely discuss work related matters such as species identification, exchange of books, articles, and specimens, and publications. These correspondences are an example of how information flows across provinces and countries within information networks and show how Buller situated himself as an important botanical resource within Manitoba.

Over his 43-year career, Buller contributed to mycology. During the early twentieth century, fungi were classified as plants. However, discoveries were being made that countered this organization.[194] Buller helped to synthesize mycological findings of the late nineteenth century and add his own important work.[195] P.H. Gregory, one of Buller's former students, discusses Buller's significant contributions in his lecture, "The fungal mycelium - an historical perspective," concluding that although some of Buller's conclusions require "editing," a considerable portion of his research has been confirmed in the intervening years.[196] Buller

[194] Gregory, "The Fungal Mycelium," 4.

[195] Ibid.

[196] Ibid., 8.

received some contemporary recognition, but his findings have not been included into the mycological literature.[197]

Buller's efforts did not go completely unnoticed as he was the recipient of many honors and honorary degrees over his career. These awards include, the Flavelle Medal of the Royal Society of Canada in 1929, the Medal of the Manitoba Natural History Society in 1936, and the Royal Medal of the Society of London in 1937. Additionally, Buller was recognized through other institutions by receiving honorary degrees: University of Manitoba LL.D in 1924, University of Saskatchewan LL.D in 1928, University of Pennsylvania D.Sc. in 1933, and the University of Calcutta LL.D in 1937. His reputation as a superlative speaker preceded him and he was invited to speak at many institutions over the course of his career. He was sought for his ability to give coherent and lively talks. Some of these lectures include 1927 Norman Wait Harris Foundation lecturer at Northwestern University, 1941 summer lecturer at Louisiana State, 1942 Hitchcock Professor at the University of California-Berkeley, and 1942 Schiff Foundation lecturer at Cornell University. These lectures across North America helped to introduce Buller's lecturing methods and botanical research to new audiences.

Buller's reputation and notoriety did help him in attracting several graduate and doctoral students over his tenure at the University of Manitoba.[198] Buller supervised the first two PhD candidates from the University of Manitoba. William F. Hanna graduated in 1928 and was the first student in Western Canada to receive a PhD. Second was John H. Craigie who graduated in 1930. Both Hanna and Craigie went on to work at the Dominion Rust Research Laboratory.[199]

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[197] Gregory, "The Fungal Mycelium," 9.

[198] Estey, *Early History of Plant Pathology,* 274.

[199] Buller had a role in the creation of this lab which will be discussed later. The lab was later renamed the Cereal Research Center. The lab was closed in April 2014 due to federal budgetary restraints.

Dorothy Newton-Swales from Quebec was also one of Buller's students. She was the fourth student and first woman to earn a PhD from the University, receiving her degree in 1932.[200] Newton-Swales also was a lecturer in the department, replacing Charles Lowe while he was on leave.[201] Irene Mounce from British Columbia, was the first recipient of the Hudson's Bay Company scholarship for the University in 1921 and worked with Buller to receive her MSc. Buller also supervised Harold J. Brodie, Ruth Macrae, and Thomas C. Vanterpool, all of whom went on to become prominent mycologists or plant pathologists.[202]

Working at the University of Manitoba afforded Buller a unique opportunity in Canada. When he arrived in Winnipeg, Buller was the only plant pathologist in the country.[203] Working in the Canadian prairies was a good fit because Buller was already interested in rusts and diseases prior to his move to Winnipeg. In his 1903 lecture series in Birmingham, Buller had included a talk on Canadian rusts.[204] Central North America was prone to wheat rust epidemics, during the early part of the century, often resulting in 50-70% loss in the wheat yield and wiping out entire fields.[205] 1916 was a particularly devastating year on the wheat crop and consequently the food supply, compounded by the needs of World War I soldiers. This was followed by

[200] Buller had a larger proportion of women graduate students in comparison to their numbers in post-secondary education overall. He considered women just as capable scientists as men. He was extremely polite and respectful to all students regardless of gender. Goldsborough, "Reginald Buller," 32.

[201] Estey, *Early History of Plant Pathology,* 276.

[202] Ibid., 274.

[203] Estey, "A. H. R. Buller: Pioneer Leader in Plant Pathology," 18.

[204] Ibid., 17.

[205] P. Peterson et al., "Prevalence and Distribution of Common Barberry, the Alternate Host of *Puccinia Graminis*, in Minnesota," *Plant Disease* 89, no. 2 (2005) 159.

epidemics in 1919, 1921, and 1923.[206] Partially because of national duty and partially because of scientific interest Buller then became even more concerned with the wheat rust issue.[207]

Buller was instrumental in the meeting of the First Cereal Rust Conference in Winnipeg in 1917, bringing researching together to help discuss the rust diseases.[208] On June 1, 1917 Buller sent out a letter entitled "Memorandum on the rust disease of wheat" to the director of the Central Experimental Farm in Ottawa, the president of the University of Saskatchewan, and the president of the University of Manitoba in which he called for the Department of Agriculture and the Agricultural College in Winnipeg to combat the wheat rust problem.[209] This letter was the likely catalyst for the conference held in August.[210] However, during the World War I little else could be done with the scarcity of resources.[211] To combat the rust in the meantime, Buller spearheaded a public campaign to eradicate the common barberry which was a popular ornamental shrub and a host for the rust, *Puccinia graminis,* which is one of the fungi that causes so much destruction.[212] These plants are still banned in many communities across North America since they are known hosts for the rust. He also published his book, *Essays on Wheat* (with fifty illustrations in the text) in 1919 *"…*to put on record facts which have an important bearing upon the agricultural progress of both Canada and the United States."[213] The book was popular with

[206] W. E. Sackston, "John Hubert Craigie," *Biographical Memoirs of Fellows of the Royal Society* 39, no. February (1994) 133.

[207] Goldsborough, "Reginald Buller," 26.

[208] Estey, "A. H. R. Buller: Pioneer Leader in Plant Pathology," 19.

[209] Estey, *Early History of Plant Pathology,* 88.

[210] Ibid.

[211] Sackston, "John Hubert Craigie," 133.

[212] Goldsborough, "Reginald Buller," 26.

[213] Estey, "A. H. R. Buller: Pioneer Leader in Plant Pathology," 19; A. H. Reginald Buller, *Essays on Wheat: Including the Discovery and Introduction of Marquis Wheat, the Early History of Wheat-Growing in*

one reviewer in *Nature* stating, “Prof. Buller’s “Essays on Wheat” are among the most interesting things we have seen for a long time.”[214] After the war, the Second Cereal Rust Conference was held in 1924 at which the decision was made to establish the Dominion Rust Research Laboratory in Winnipeg, due to Buller’s instigation.[215] During this meeting Buller stated, “…immunity to rust was a Mendelian character and as such could be handled by a skillful plant breeder…”[216] The eradication of barberry bushes helped lessen the prevalence of wheat rust however, the fungi can reproduce without the barberry host.[217] As Buller predicted, breeding of rust resistant wheat beginning in the 1940s, was the most successful preventative measure to the destruction of wheat crops from rust blights.[218] The research for which was undertaken in research laboratories like the one established in Winnipeg.

The concept for this type of federally funded lab, like the Dominion Rust Research Laboratory, had been previously considered. However, the lab had been planned to be located at one of the existing research stations like Brandon, Manitoba or Indian Head, Saskatchewan.[219] In his 1917 memorandum, Buller argued that Winnipeg was a superior location for its proximity to the University of Manitoba and the Agricultural College to provide scientists and research

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Manitoba, Wheat in Western Canada, the Origin of Red Bobs and Kitchener, and the Wild Wheat of Palestine. (New York: The Macmillan Company, 1919). vii.

[214] E. J. Russell, “Wheat and Wheat-Growing,” *Nature* 105, no. 2634 (1920) 224.

[215] Sackston, “John Hubert Craigie,” 133; Goldsborough, “Reginald Buller," 29. The organization, now defunct, was in the Cereal Research Building on the University of Manitoba Fort Gary Campus.

[216] Estey, “A. H. R. Buller: Pioneer Leader in Plant Pathology,” 19.

[217] Gail L. Schumann and Kurt J. Leonard, “Stem Rust of Wheat (Black Rust),” *The Plant Health Instructor*, 2000.

[218] Rina Shaikh-Lesko, “Wheat Whisperer, circa 1953,” *The Scientist*, June 2014.

[219] Goldsborough, “Reginald Buller," 29. Buller felt that the Dominion Rust Research Laboratory was important and consequently bequeathed his library to the organization to help future researchers, Johnson, *Catalogue of the Buller Memorial Library,* 9.

resources, such as libraries.[220] He also noted that the Grain Exchange was located in Winnipeg and it was a central location in which many agricultural conventions took place, making it a prime destination for researchers.[221] Eventually the government agreed to Buller's suggestions and opened the Dominion Rust Research Laboratory in 1925 (Figures 11 and 12). This laboratory was a significant asset to the agricultural and plant science communities in Winnipeg and on a smaller scale to Buller and his students as several of them secured jobs at the lab.

Buller's impact on the scientific community in Manitoba cannot be understated. Initially he developed modern New Botany teaching in Winnipeg and created a scientific community in the province. He worked on community outreach and education, delivering public lectures and promoting the cause of the University, and lobbying the government. Buller also actively pursued his own research and vigorously published his work and participated in international scientific organizations. Through all of his work, Buller received many accolades but his achievements have been left out of the scientific records.

[220] Goldsborough, "Reginald Buller," 29.

[221] Ibid., 30.

Figure 11. Dominion Rust Research Laboratory with former Fusarium Laboratory to left, c. 1930. Courtesy Agriculture and Agri-Food Canada.

Figure 12. Dominion Rust Research Laboratory with view of Tier Building and others, c. 1933. Courtesy Agriculture and Agri-Food Canada

Chapter 3: Wall Charts in Buller's Scientific Pedagogy

Although Buller may not have received the level of recognition of his Eastern peers as outlined in chapter two, he did remain a highly respected researcher and teacher. Buller published his research fairly regularly in international journals in addition to his *Researches on Fungi* book series. He also published several other books and was involved with the translation of Tulsane's *Selecta Fungorum Carpologia,* a significant mycological text.[222] Students and colleagues alike appreciated Buller's unique style and approach to teaching which made him a successful professor at the University of Manitoba. His pedagogical methods were greatly influenced by his time in Germany studying New Botany techniques and they were enhanced by his own concepts on science education. As previously discussed, prior to Buller's arrival in Manitoba, science education in the province was administered mainly by clergy and would be categorized as natural history. Buller, as a highly educated botanist, brought modern scientific practice and New Botany to Manitoba. This chapter will investigate Buller's pedagogy and its connection to the visual culture of scientific wall charts in early twentieth century education.

By the late nineteenth century, visual materials, including scientific illustrations, were becoming more prevalent in an increasing variety of mediums, according to historians Galison, Anderson, and Kemp. Joining this trend, scientists frequently began to use visual imagery to help explain and communicate their work. The reliance on visual imagery overlapped with changes in pedagogical theory from the late eighteenth century, which valued learning through visuals

[222] Buller published *Essays on Wheat* in 1919, *Practical Botany* in 1929, *The Fungi of Manitoba* in 1929 with G. R. Bisby and John Dearness, and *The Fungi of Manitoba and Saskatchewan* with Bisby, Dearness, W.P. Fraser, and R.C. Russell in 1938. He also helped produce an English translation of Tulsane's *Selecta Fungorum Carpologia* in 1931. Johnson, *Catalogue of the Buller Memorial Library*, 11-12.

rather than relying solely on lectures.[223] The inclusion of visual imagery was thought to increase engagement and made lectures visually interesting. For scientist-educators, this shift in the cultural attitude towards visual imagery changed the importance of artistic abilities. As literary studies scholar Jonathan Smith and communications scholar Jean Trumbo highlight, careful crafting of scientific images was imperative for the development of teaching visual literacy and communicating knowledge.

Although scientists always needed some degree of artistic ability, the new reliance on and expectations of visual materials to explain and communicate scientific research heightened the need for scientists to also be artists. This did not mean that illustrations should be replicas of nature, but rather crafted in a way to most effectively communicate the scientist's message.[224] Over the course of the history of visual communications, the way in which science has been represented has changed.[225] As visual culture scholars Lorraine Daston and Peter Galison note, a method of illustration called "truth-to-nature" arose after the Enlightenment in reaction to the "perceived overemphasis" of the variability in nature in earlier periods.[226] When applying this technique, the artist-scientist combines information and omits and variations or anomalies to create an average of the specimen. Additionally, artist-scientists were expected to be able to "analyze and synthesize impressions" and be a "genius of observation" to depict a truth or reality

[223] Zevenhuizen, "Uit de Drukpers En van de Tekentafel."

[224] Jean Trumbo, "Making Science Visible: Visual Literacy in Science Communication," in *Visual Cultures of Science: Rethinking Representational Practices in Knowledge Building and Science Communication*, ed. Luc Pauwels (Hanover, NH: Dartmouth College Press, 2006) 271. Similarly, photography could have been used to give realistic representations of nature. Photography was considered objective by many although some questioned its objectivity from its beginnings. However, botanists in particular were slow to wholeheartedly embrace this technology because it lacked the ability for easy manipulation like more traditional illustrative methods like drawing or painting. For more information on this period see Lorraine Daston and Peter Galison, *Objectivity*.

[225] Visual communication is defined as the utilization of images to transfer knowledge. Trumbo, "Making Science Visible," 270.

[226] Daston and Galison, *Objectivity*, 58. Consult Daston and Galison's *Objectivity* for a further discussion of these visualization techniques and their historical uses.

that was only visible after significant time spent observing the specimen.[227] Johann Wolfgang von Goethe summarized the technique in 1798 stating, "To depict it, the human mind must fix the empirically variable, exclude the accidental, eliminate the impure, unravel the tangled, discover the unknown."[228] Truth-to-nature involved a scientist/naturalist observing an organism and idealizing it by omitting imperfections, simplifying forms, and highlighting special features to create a representation of a perfect example of that species, as represented so well with the scientific illustrations of radiolaria by Ernst Haeckel in his publications as early as 1862.[229] Haeckel was a well-known polymath of the nineteenth century, famous for popularizing a version of Darwin's theories in Germany as well as developing his own scientific theories and creating aestheticized scientific illustrations which was influenced by the Art Nouveau movement and inspired other Art Nouveau artists.[230] As art historian Martin Kemp points out, at their core art and science are similar in that they both "gratify our systems of perception, cognition, and creation" with an emphasis on aesthetics.[231] Artists and scientists both seek to discover and represent the truth, although in different ways.[232]

In the twentieth century another method of scientific visualization developed called "trained judgement," which relies on the expertise of the scientist to "synthesize, highlight, and

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[227] Daston and Galison, *Objectivity*, 58.

[228] Johann Wolfgang von Goethe, "Erfahrung und Wissenschaft" in *Goethes Werke*, ed. Dorothea Kuhn and Rike Wankmüller, 25. 7th. Munich: 1975-6 translated and quoted in Daston and Galison, *Objectivity*, 59.

[229] Stephanie Moser, "Making Expert Knowledge through the Image: Connections between Antiquarian and Early Modern Scientific Illustration," *Isis* 105, no. 1 (March 2014) 62; Lorraine Daston and Peter Galison, *Objectivity* (New York: Zone Books, 2007) 59.

[230] There is a wealth of scholarship on Ernst Haeckel whose career turned somewhat controversial which this paper will not discuss. The most extensive scholarship on his has been done by Erica Krausse. See her work in *L'ame au corp: Art et science 1793-1993 f*or more information.

[231] Kemp, *Visualizations,* 2.

[232] Ibid., 2-3.

grasp relationships" within images.[233] As Daston and Galison explain, trained judgement arose as a reaction to the emphasis on objective images of mechanical reproductions.[234] Mechanical reproductions did not allow for modifications to refine images. At the same time scientists-artists did not want a return to truth-to-nature which they felt overemphasized idealization and aesthetics.[235] Truth-to nature created the added problem of developing only one representation for an entire species.[236] Trained judgement remedied some of the issues of these previous techniques by leaving the creation and use of visualizations to experts. With trained judgement there was a move away from idealization and a single representation of a species. Instead it relied on the expert intuitions of the scientist to interpret images and utilize them.[237] In this way, trained judgement is similar to being able to distinguish a visual style.

Although each of these methods came in and out of favor at various times, their use may overlap.[238] Botanists used truth-to-nature and trained judgement to create scientific illustrations even after the latter had fallen out of favor elsewhere.[239] Photography and other forms of mechanical reproduction had become popular for their perceived objectivity. Because photography did not allow for the manipulation of imagery that botanists desired, they were slow to adopt this technique and continued to prefer truth-to-nature illustration longer than other

[233] Daston and Galison, *Objectivity*, 311-314.

[234] Ibid., 311.

[235] Ibid., 315.

[236] Ibid.

[237] Ibid., 313.

[238] Ibid., 105.

[239] Ibid.

disciplines.[240] Even proponents of photography admitted that it could not replace illustration for botanists.[241]

Art historian Martin Kemp notes that, artists and scientists have developed a shared way of seeing and processing the natural world.[242] Artistic and scientific practice overlap and influences transfer between them through three main ways: observation, experimentation, and visualization. Observation is at the core of both science and art and practioners must spend significant time observing nature in ways that others do not in order to learn and represent the natural world truthfully.[243] Considering the process of scientific and artistic undertakings, experimentation is an integral step. Both artists and scientists think and test for outcomes, although the final product is held to a different set of expectations and standards. Additionally, visualization is a fundamental mode of communication in both arts and sciences. It is largely accepted that artists create visual representations and have styles but so too do scientists. Aesthetic and design choices always exists in visual representations which are personal to each artist and creates a unique style.[244] To communicate knowledge, scientists and artists share pictorial conventions including, "analytical description, abstraction, and process."[245] Scientists utilized common artistic techniques and methods such as perspective, modulation of color, and abstraction to develop pictorial conventions and craft the visual language of botany.[246] By the

[240] Catherine de Zegher, "Ocean Flowers and Their Drawings," in *Ocean Flowers: Impressions from Nature*, ed. Carol Armstrong and Catherine de Zegher (New York; Princeton: Princeton University Press, 2004) 80; Daston and Galison, *Objectivity*, 105.

[241] Daston and Galison, *Objectivity*, 105.

[242] Kemp, *The Science of Art*, 1.

[243] Kemp, *Visualizations,* 2-3.

[244] Ibid., 5.

[245] Ibid., 5-6.

[246] Moser, "Making Expert Knowledge," 63.

early twentieth century, it was an important skill to be able to communicate scientific ideas both verbally and visually.

Of course, not every scientist was an adequate artist, and some had to hire artists or borrow illustrations. Because of this a scientist's artistic ability could be an important component to their scientific identity. Combined with the New Botany emphasis on practical work and visual representation, the idea of the use of visuals in education was widespread by the time Buller began teaching in the beginning of the twentieth century. Although the concept was not uncommon, its practice was much less so. Likely from his New Botany education, Buller embraced visual materials as an effective way to communicate scientific concepts and therefore utilized them liberally. He emphasized visual learning for his students, enhancing the educational experience through his consistent use of visual materials in the classroom.

As Galison and Jones have stated, utilitarian visual objects including wall charts have been neglected by art historians.[247] Part of Buller's visual material holdings in the Archives & Special Collections at the University of Manitoba included a significant collection of wall charts. This collection was comprised of 173 commercial mass-produced lithographs and 162 watercolor wall charts designed and hand-painted by Buller and his assistants. Yet this important collection only made its way to the archives by happenstance.

As the Broadway University campus was being cleared out for demolition, Buller's two map cabinets were split up – one going to the Fort Garry campus and the other going to the Delta Marsh Field Station. Tom Booth transferred the first cabinet to the Archives. This cabinet held a majority of the Buller wall chart collection and the cabinet remains in the Archives. The Delta Marsh Station was being cleaned, and Buller's second cabinet was moved to the hallway outside

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[247] Jones and Galison, *Picturing Science*, 6.

Gordon Goldsborough's office in the Buller Building on the Fort Garry campus. Goldsborough found more of Buller's wall chart collection inside this cabinet and contacted the University Archives transfer the materials.[248] Situations such as this are not uncommon for the preservation of archival materials, demonstrating why archival work can be so difficult simply for the lack of resources. In this case, I was lucky to work with a robust archival collection, including a vast array of visual materials.

The use of mass-produced wall charts originated in Germany, and they were widely available and used across Europe and North America by the time Buller took up his post at the University of Manitoba. Wall charts were introduced in the 1820s for teaching primary school classes.[249] They were small, only about 8 x 11 inches, and featured everyday objects and basic knowledge such as animals and the seasons.[250] Wall charts quickly gained popularity, even being recommended by school administrations, and their usage spread to other levels of education.[251] From 1870-1920, wall chart usage experienced a 'golden age' sold as large, 32 x 26 inch mass produced sets, utilized in every level of education, for a wide range of subjects.[252] Complete sets cost between $45 and $115USD at the turn of the century, which was not prohibitive, particularly with the advent of faster and cheaper printing technologies.[253] Since they were considered such a valuable educational tool, many school districts and universities considered

[248] Shelley Sweeney (Head of Archives & Special Collections, University of Manitoba), email message to author, 15 August 2017. Dr. Sweeney provided the provenance of the Buller wall chart collection.

[249] Bucchi, "Images of Science in the Classroom," 163.

[250] Ibid.

[251] Ibid.

[252] Hunt Institute for Botanical Documentation, "Persons, Collections and Topics: Wall Charts," 2017, http://www.huntbotanical.org/art/show.php?12.

[253] Rudolf Schmid, "Wall Charts (Wandtafeln)," 471–72.

the expense worthwhile.[254] Wall charts were particularly popular in botany classrooms, allowing a large number of students to view the internal and external structures of plants at the same time.[255] Some of the key figures of New Botany methodologies, such as Anton de Bary, had a hand in creating mass-produced wall chart sets, and the initial botanical wall chart sets focused on integral components to New Botany education, plant and fungal anatomy, morphology, and systematics.[256] As a proper New Botany professor, one of Buller's first purchases as the head of the Botany Department were botanical wall chart sets.[257]

What remains of Buller's wall chart collection at the University of Manitoba archives, includes parts of six commercially available lithograph sets for a total of 173 charts. The lithographs are from the first published botanical wall chart set, plant physiologist Leonard Kny's (1841-1916) *Botanische Wandtaflen* (*Botanical Wallcharts*) (Figure 13).[258] Kny popularized the use of the over-sized wall charts with large colored details and his set became one of the most famous.[259] The series was in production from 1875 to 1911 and the complete set cost $115 USD in 1911.[260] By looking through Buller's mass-produced wall chart sets I have noted that *Botanische Wandtaflen* comprises the largest part of Buller's lithograph collection,

[254] Jakob Evertsson, "Classroom Wall Charts and Biblical History: A Study of Educational Technology in Elementary Schools in Late Nineteenth- and Early Twentieth-Century Sweden," *Paedagogica Historica*, 2014, 683.

[255] Bucchi, "Images of Science in the Classroom," 165.

[256] Hunt Institute for Botanical Documentation, "Persons, Collections and Topics: Wall Charts"; Schmid, "Wall Charts (Wandtafeln)," 472.

[257] Buller, "Report on the Botanical and Geological Departments 1904-1905," 8.

[258] Frans Antonie Stafleu and Richard S. Cowan, *Taxonomic Literature: A Selective Guide to Botanical Publications and Collections with Dates, Commentaries and Types*, 2d ed., vol. 2 [Authors H-Le] (Utrecht: Bohn, Scheltema & Holkema, 1979) 586.

[259] Schmid, "Wall Charts (Wandtafeln)," 471.

[260] Ibid., 472.

holding 77 out of the entire set of 120.[261] The next largest portion of Buller's lithograph wall charts are from plant pathologist Albert Bernhard Frank (1839-1900) and pharmacist Alexander Tschirch's (1856-1939) *Pflanzenphysiologische Wandtafeln* (*Plant Physiology Boards*) (Figure 14). Published from 1889 to 1894 and sold for $45USD in 1894, this set was also widely sought after.[262] Buller purchased 43 out of 60 from the set. Buller also purchased significant portions of Blakeslee et. al. *Tabulae Botanicae* (c. 1906-1908), Albert Peter's *Botanische Wandtafeln* (1892-1914), Carl von Tubeuf's *Pflanzenpathologische Wandtafeln* (c. 1906), and Hilary Jurica's *Jurica Biology Series* (c. 1920s). With the exception of the *Jurica Biology Series* which was manufactured in the United States, all of Buller's sets were produced in Germany. It is unclear whether Buller ever owned the entirety of any of the sets or if he purchased the charts separately. The charts are well worn and many have hand-written descriptions in the margins indicating that they were frequently used. Some of the charts may have been lost to damage from regular use in the classroom.

Buller was an enthusiastic lecturer whose excitement for the botanical science was infectious to his students.[263] He went to great lengths to ensure that his lectures were visually stimulating to enhance the learning experience for his students, including a range of visual material, from fresh plant specimens, wax models, lantern slides, and wall charts. New Botanists such as Buller valued visual material in the classroom and considered these components important to the educational process. It was not only Buller's New Botany education that influenced his extensive use of visual material; he is distinctive because he also thought visually.

[261] Stafleu and Cowan, *Taxonomic Literature*, 586.

[262] Schmid, "Wall Charts (Wandtafeln)," 472.

[263] Estey, "A. H. R. Buller: Pioneer Leader in Plant Pathology," 21.

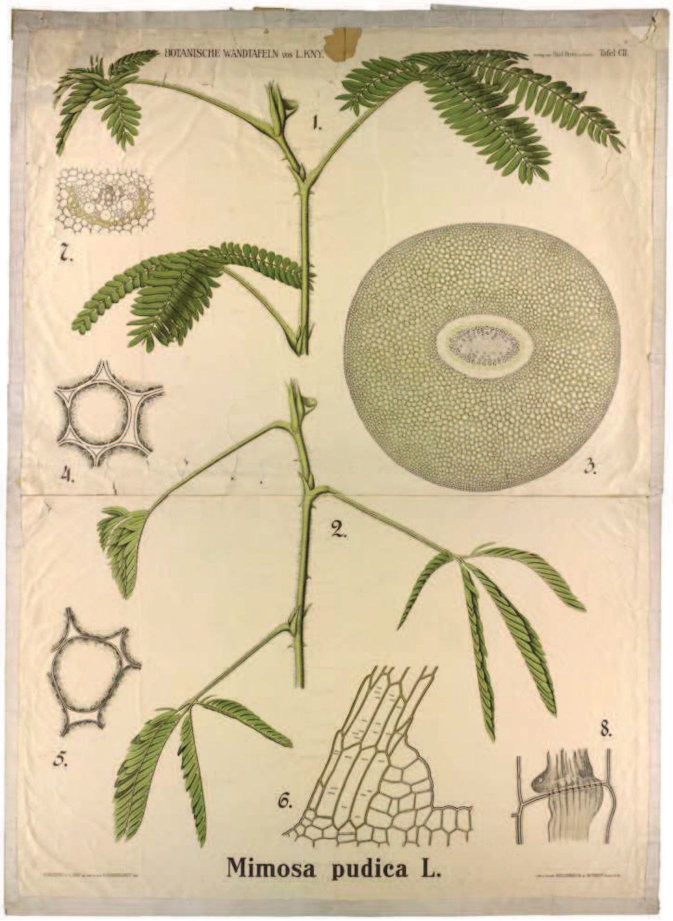

Figure 13. Leonard Kny, *Mimosa pudicia L.* from the series *Botanische Wandtaflen*, 1875-1911.
UMA, Buller fonds (MSS 184), A.04-025, Drawer 4, Folder 20, No. 1

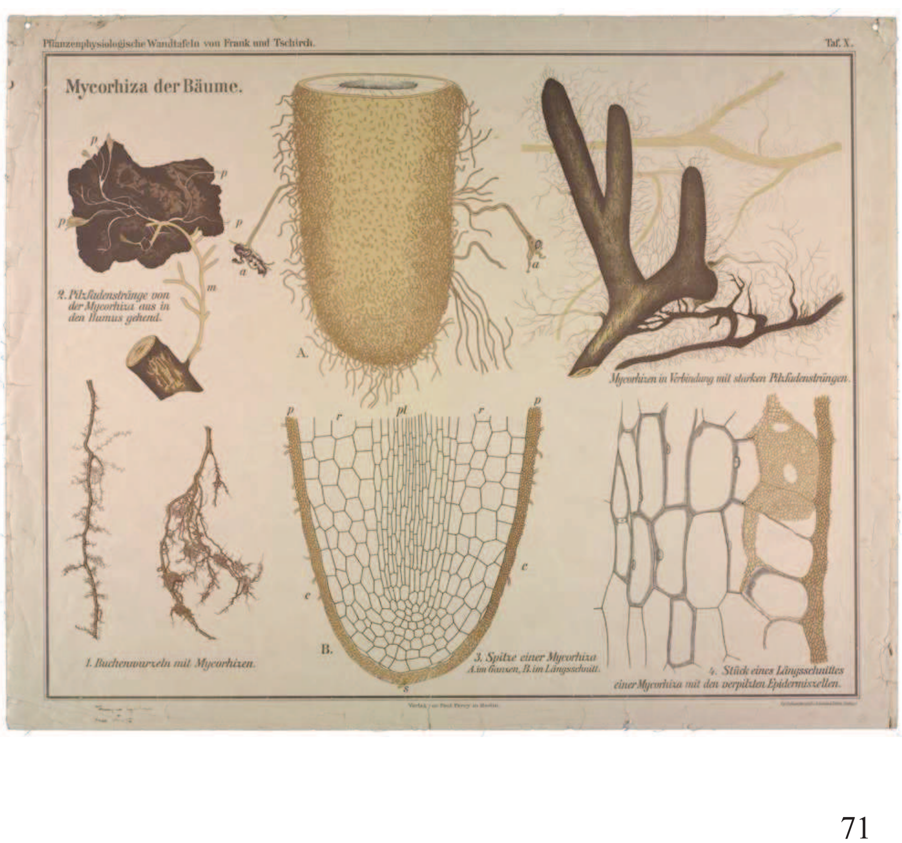

Figure 14. Albert Bernhard Frank and Alexander Tschirch*, Mycorhiza der Baume* from the series *Pflanzenphysiologische Wandtafeln,* 1889-1894. UMA, Buller fonds (MSS 184), A.04-025, Drawer 4, Folder 10, No. 4.

There was a larger trend within New Botany to emphasize visual material, but the inclusion of illustrations does not indicate that the scientist is visually acute.[264] Buller saw the world through a visual lens and was continually aware of the important role played by visual material within the scientific community. Partially due to this visual approach, Buller considered his artistic abilities as part of his scientific identity and he regarded illustrations as integral components of scientific research and education.

Buller played the difficult dual role of science expert and science communicator; he was an avid researcher but also created his own wall charts and illustrations. While other botanists drew their own illustrations and wall charts, Buller's method was different because he created wall charts for all levels of classes rather than simply creating specialized charts for higher level courses or to illustrate his new research. Buller considered himself foremost a scientist, but he put considerable effort into visual representations as a science communicator. Regardless of the medium with which he was working, Buller continually strove to ensure his illustrations and wall charts fulfilled his goal of being clear, concise, and aesthetically pleasing. As Bucchi has shown, wall charts were thought to enhance students' ability learn by capturing their attention and introducing material in a new way.[265] This focus on visual representation made his lectures more successful as he brought the concepts of New Botany to the Canadian prairies.

Buller rarely lectured without some sort of visual material. While a guest lecturer at Northwestern University in Chicago in 1927, Buller brought over 400 slides.[266] Some broke during his travels, that he could not replace while away, so he wrote to his friend and fellow

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[264] Martin Kemp, *Seen/Unseen: Art, Science, and Intuition from Leonardo to the Hubble Telescope* (Oxford; New York: Oxford University Press, 2006) 9.

[265] Bucchi, "Images of Science in the Classroom," 165 and 169.

[266] Letter from A.H.R. Buller to W.B. Grove, 8 December, 1927, Box 6, Folder 7, A.H. Reginald Buller fonds, University of Manitoba Archives & Special Collections, University of Manitoba.

botanist in England, W.B. Grove, to have them remade.[267] Although he used many visual materials, he utilized each one deliberately, as he felt that illustrations must be made purposely with "a particular point in mind."[268] As Buller knew, visual materials are not simply additions to lectures but key aspects to scientific communication.[269] Buller was particular about visual materials that accompanied his work and created many of the visual aids himself. Buller was precise in creating his aids, sometimes taking over ten hours to create one slide. Even if the visual aid was going to be used only twice, Buller considered the effort worthwhile.[270]

As mentioned previously, botany required sufficient artistic skill and most botanists of the day were adequate draftsmen. Artistic skill was necessary for sketching specimens in the field and crafting finished illustrations.[271] It also highlighted a scientist's observational abilities, therefore, some scientists linked their artistic talent to their scientific identity. Artistic merit of illustrations was not the only important factor, but also how the scientist could utilize them to communicate their work. It was important for scientists to be able to communicate the visual language of their illustrations.[272] Visual sociologist, Luc Pauwels highlights that science illustration are not about simply replicating the natural world but rather making it comprehensible and accessible.[273] Additionally, since many of the images and concepts being

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[267] Letter from A.H.R. Buller to W.B. Grove, 8 December, 1927, Box 6, Folder 7, A.H. Reginald Buller fonds, University of Manitoba Archives & Special Collections, University of Manitoba.

[268] Letter from A.H.R. Buller to Mr. Prettie of the Alberta Wood Preserving Company, 12 February, 1926, MSS 184 A.04-25, Box 1, Folder 1, A.H. Reginald Buller fonds, UMA, University of Manitoba.

[269] Pauwels, "The Role of Visual Representation," vii.

[270] Letter from A.H.R. Buller to Elsie Wakefield, 11 May 1915, MSS 184 A.04-25, Box 5, Folder 1, A.H. Reginald Buller fonds, UMA, University of Manitoba.

[271] Jonathan Smith, *Charles Darwin and Victorian Visual Culture* (Cambridge: Cambridge University Press, 2006) 4.

[272] Smith, *Charles Darwin and Victorian Visual Culture,* 35.

[273] Pauwels, "The Role of Visual Representation," viii.

depicted were rather new, a cohesive visual language had yet to be developed across the field. Science communicators with the ability to directly develop and explain the visual language of their illustrations were an asset. Scientists with artistic ability benefited, as their concepts did not have to be translated by an artist, since even minute changes within an illustration can alter its message. This is not to say, however, that every scientist embraced visuals or implemented them well.

Buller was uncompromising with his own visuals. He was very precise in creating his aids, often taking hours to work on illustrations.[274] He was even willing to skip vacations, simply to perfect his drawings.[275] Buller judged these visual materials as an integral component in their own right, which required a significant commitment to properly create. He also recognized that he might be criticized for his illustrations as he critiqued others. While working on the manuscript of *Researches on Fungi Volume II,* Buller commented that he only had one illustration left before the work was finished but he was extremely careful because the illustrations would "meet with the critical eyes of many a keen observer once they have been published."[276] Yet once completed, Buller was satisfied with his demonstration of artistic and scientific skill.[277]

Buller's artistic aptitude was recognized by his scientific colleagues. Dominion Botanist, Hans T. Güssow attributed Buller's success in part to his talent stating, "…it was patent that with

[274] Letter from A.H.R. Buller to Elsie Wakefield, 11 May 1915, A.H. Reginald Buller fonds; Letter from A.H.R. Buller to Elsie Wakefield, 27 August 1917, MSS 184 A.04-25, Box 4, Folder 7, A.H. Reginald Buller fonds, UMA, University of Manitoba.

[275] Letter from A.H.R. Buller to William Fielding Hanna, 12 November 1931, MSS 184 A.04-25, Box 3, Folder 1, A.H. Reginald Buller fonds, UMA, University of Manitoba.

[276] Letter from A.H.R. Buller to Elsie Wakefield, 17 April 1917, MSS 184 A.04-25, Box 5, Folder 1, A.H. Reginald Buller fonds, UMA, University of Manitoba.

[277] Letter from Wallage & Gilbet Ltd. to A.H.R. Buller, 23 August 1915, MSS 184 A.04-25, Box 5, Folder 5, A.H. Reginald Buller fonds, UMA, University of Manitoba.

such a wonderful foundation, Buller would rise to the height of his profession, which he has indeed reached at a comparatively early age, owning to his self-discipline, … coupled with artistic, mechanical, and ingenious skill."[278] Others approached Buller for advice on artistic matters. Royal Botanic Gardens, Kew mycologist Elsie Wakefield, asked his advice on several occasions regarding types of paints for illustrations.[279] Buller took the request seriously and responded promptly, sending not only paints but a set of paint brushes as well.[280] Buller sent another letter to Wakefield shortly thereafter with "tips" for using the brushes to get the desired effect for her illustrations.[281] Some botanists like, Stuart Gager and Dame Helen Gwynne-Vaughan admired Buller's work and talent so much that they asked to reproduce some of his illustrations in their publications. Buller consented but with strict stipulations that he must be credited and the illustrations could not be redrawn.[282] Buller spent significant effort on the creation of his illustrations, no matter how simple, and he took pride in their appearance and his work.

Visual materials were not important only in Buller's work but also in the work of others as well. Buller recognized artistic talent in colleagues, remarking of the former Chair of the Botany Department at the University of Birmingham, Dr. West, "I considered [him] to be one of the ablest of the younger British botanists… His memory was splendid and his illustrations most

[278] Hans T. Güssow's Address for Dinner at the Chateau Laurier, Ottawa in Honor of A.H.R. Buller, A.H. Reginald Buller fonds, 2.

[279] Letter from Elsie Wakefield to A.H.R. Buller, 5 September 1915, MSS 184 A.04-25, Box 5, Folder 1, A.H. Reginald Buller fonds, UMA, University of Manitoba.

[280] Letter from Elsie Wakefield to A.H.R. Buller, 23 August 1915, A.H. Reginald Buller fonds.

[281] Letter from Elsie Wakefield to A.H.R. Buller, 23 August 1915, A.H. Reginald Buller fonds; Letter from Elsie Wakefield to A.H.R. Buller, 5 September 1915, A.H. Reginald Buller fonds.

[282] Letter from A.H.R. Buller to Dame Helen Gwynne-Vaughan, 9 September 1926, MSS 184 A.04-25, Box 6, Folder 10, A.H. Reginald Buller fonds, UMA, University of Manitoba.

excellent. His influence upon his students was stimulating to a high degree."[283] Buller had such high standards for his own illustrations that he also judged the publications of scientific colleagues, in part, on their illustrative material, commenting on the accuracy, clarity, and naturalism of the figures.[284] Buller's aesthetic critiques even spread to an entire country when Buller wrote to a colleague during a trip around the United States lamenting the lack of good color illustrations in American mycology.[285] Although on a small scale, this was a call to improve the visual material available for an entire field.

Although he did not think of himself as an artist, Buller considered visual materials an integral aspect to all of his scientific work. Buller viewed the scientific world through a visual lens: spending hours perfecting illustrations before publishing his books, heavily illustrating his own lectures, and critiquing others' work based on their visual reproductions. Buller had the requisite visual literacy to develop his own images and communicate their meaning to his students. Therefore, Buller had very specific requirements for his own illustrations, sometimes modifying textbook figures and creating his own compositions, despite knowing that any alteration could modify the message of the image. Although he used many visual reproductions, he implemented each one deliberately. As Buller knew, visual reproductions are not simply additions to scientific communication, but an essential component of scientific

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[283] Letter from A.H.R. Buller to F.W. Gamble, Zoology Professor at the University of Birmingham, 9 January 1920, MSS 184 A.04-25, Box 5, Folder 8, A.H. Reginald Buller fonds, UMA, University of Manitoba.

[284] Letter from A.H.R. Buller to Dr. Howard A. Kelly, 13 May 1920, MSS 184 A.04-25, Box 1, Folder 9, A.H. Reginald Buller fonds, UMA, University of Manitoba; Draft of note from A.H.R. Buller to Dr. Gager, 15 March 1927, MSS 184 A.04-25, Box 5, Folder 7, A.H. Reginald Buller fonds, UMA, University of Manitoba.

[285] Ibid.

communication.[286] With carefully and precisely constructed visual materials, to communicate concepts, science helps to make the natural world more comprehensible.[287]

Development of Buller's Pedagogical Style

The use of visual material was a cornerstone of Buller's pedagogy. The ability to communicate clearly and effectively through visuals was an important component to Buller's concept of scientific practice. Although he utilized a range of visual material, Buller's chief interest was in drawing and watercolor. Buller's painted wall charts, in particular, are unique because he modified his own artistic style to conform to his pedagogical ideas. Wall charts were "a synthesis of art, science, and education."[288] They brought together all three disciplines in an attempt to create a better and more effective learning environment. Yet, today these objects remain relegated to university archives, unnoticed and forgotten as works of art. Although they remain "unclaimed" by art institutions, wall charts require further consideration from researchers, as they can offer insight into historical scientific, educational, and artistic practices.[289] In early twentieth century Manitoba, Buller utilized lithograph wall chart sets and his own watercolor wall charts to bring new concepts of modern botanical practice through his unique pedagogy to the prairie province. However, before he crafted his own wall charts, he began developing a scientific artistic style by drawing specimens while in school. These early sketches show Buller's developing artistic style and how it evolved as he began teaching.

[286] Pauwels, "The Role of Visual Representation," vii.

[287] Ibid., viii.

[288] Laurent, *Botanical Art,* 6.

[289] Jones and Galison, *Picturing Science*, 6.

While completing his Bachelor of Science at Mason College, Buller took copious notes, creating several sketchbooks from his class work. These drawings show a detailed, concise, and sometimes loose style. Because notes were taken for classes, he likely did not have much time to focus on each illustration. The purpose of Buller's notebooks was not to exactly replicate the organism that he saw, but rather, using the truth-to-nature technique, to give a representation of the species and to highlight the details discussed in his class. However, he did attempt to create semi-realistic illustrations in the time available, focusing on the components of each organism necessary for his classwork. These types of sketches were still considered accurate because they illustrated the "essence" of the organism's species.[290] Throughout his undergraduate education, Buller became more adept at translating the organism he was observing into his notebook for further study later. In this way, Buller was developing his ability to communicate scientific ideas.

Once Buller began studying radiolarians, the artistic influence of Ernst Haeckel is immediately apparent (Figure 15). Haeckel's *Die Radiolarien* was initially published in 1862 and in it he supported Darwin's evolutionary theories (Figure 16).[291] Haeckel's scientific work was illustrated with decorative and colorful images that he drew himself. His illustrations also became popular in their own right, and he eventually published his scientific illustrations *Kunstformen der Natur* (*Art Forms of Nature*) in two volumes in 1899 and 1904 which compiled some illustrations from previous publications plus new scientific illustrations. This work was incredibly popular within the art community, inspiring many artists, designers, and architects

[290] Moser, "Making Expert Knowledge," 62.

[291] Robert J. Richards, *The Tragic Sense of Life: Ernst Haeckel and the Struggle Over Evolutionary Thought* (Chicago: University of Chicago Press, 2008) 70. Haeckel did not completely agree with Darwinian evolution and continued to adhere to some Lamarkian beliefs.

particularly within the Art Nouveau movement.[292] Buller studied Haeckel's work while at Mason Science College as both Haeckel's scientific and artistic work were popular by the time Buller was in school in the late 1890s.[293]

Figure fifteen is a sketchbook page from one of Buller's class notebooks that shows one of his radiolaria sketches, circa 1895. Figure sixteen is one of Haeckel's illustrations from *Die Radiolarien (Radiolariens)* published in 1862. Comparing Buller's sketches to Haeckel's illustrations, the similarities are noticeable. Buller focuses on the geometric form of the organism, creating clean smooth lines, which is very similar to Haeckel's illustrations. Although Buller's and Haeckel's illustrations are beautiful they are not exact representations of what was observed. These illustrations fall into the concept of truth-to-nature. In comparing these illustrations to photos of radiolaria (Figure 17) the idealization of the forms is evident. Both Buller and Haeckel created order in the organism by smoothing the geometry of the crystalline skeleton and omitting flaws. Although the radiolaria is identifiable, Buller and Haeckel were idealizing the skeleton to develop a type for that species rather than realistically reproducing a specific individual. Haeckel's scientific publications and artistic style influenced Buller's early style by showing him ways in which scientists communicated their ideas. These illustrations helped Buller to develop and create his own style to better communicate his own scientific ideas by considering the aesthetics and message of each illustration.

Throughout Buller's school sketchbooks, his particular style begins to develop. A number of his early sketches began to show signs of the later style that he utilized for his wall chart paintings. Buller implemented a thin and confident outline of his figures. This outline helped

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[292] Richards, *The Tragic Sense of Life,* 406. The influence of *Kuntsformen der Nature* cannot be understated. His designs influenced many artists and architects including René Binet (1866–1911), architect of the Paris Exposition who designed the entry gates after Haeckel's illustrations.

[293] By the end of his life, Buller's library also included at least three of Haeckel's books, *The Riddle of the Universe, The Wonders of Life,* and *The Evolution of Man.* Johnson, Catalogue of the Buller Memorial Library, 65.

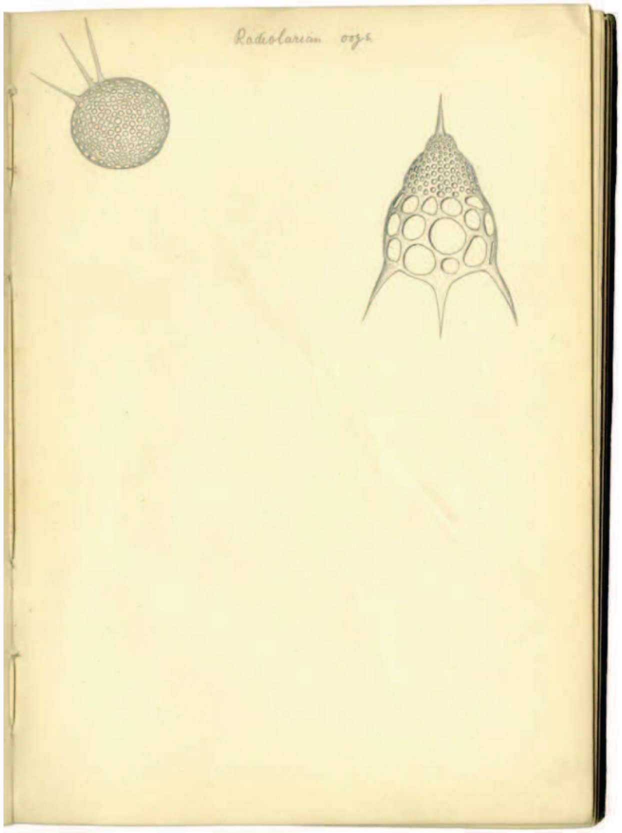

Figure 15. A.H. Reginald Buller, Notebook with radiolarians, c. 1895.
UMA, Buller fonds, PC 175 (A.075-62)

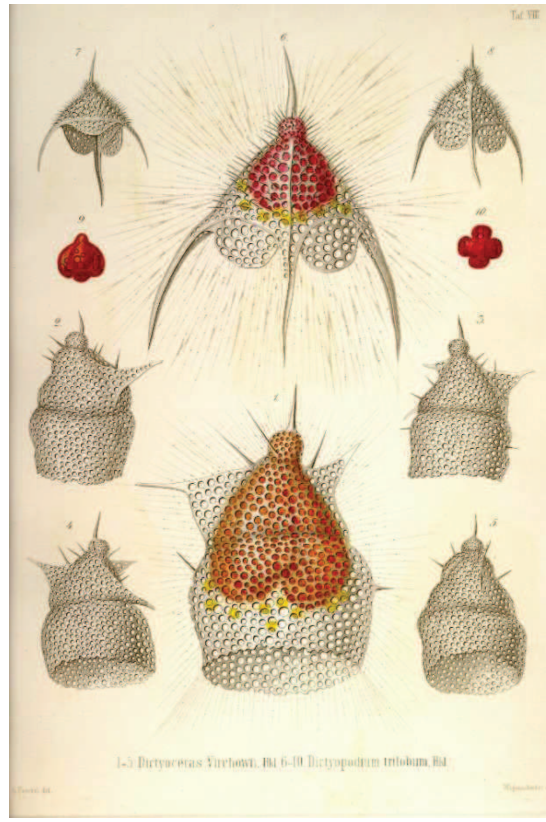

Figure 16. Ernst Haeckel. Tafel 8 from *Die Radiolarien,* 1862. © 1998 Kurt Stüber

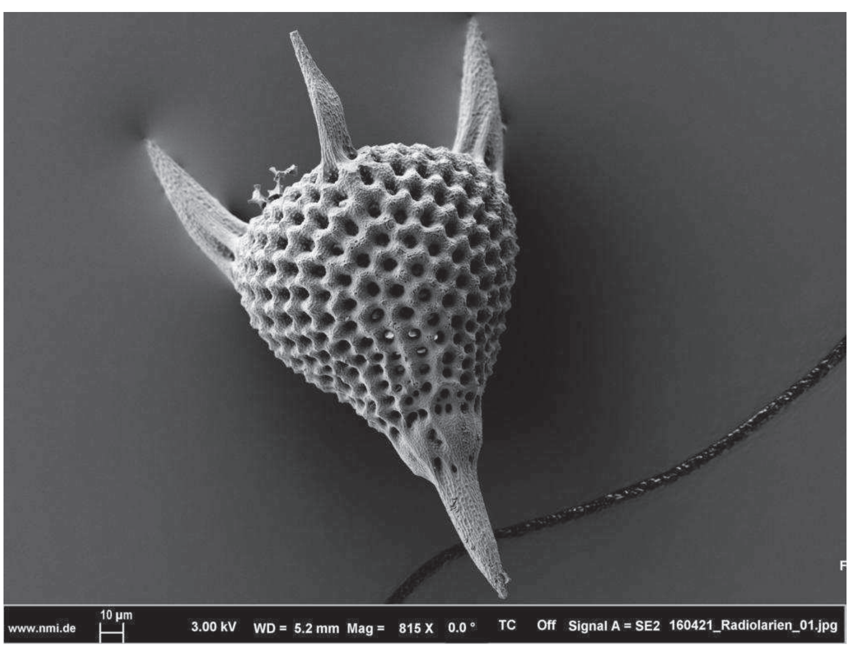

Figure 17. Electron microscope image of radiolarian.
Courtesy Wilfried48

to define the figure and its components for clarity and ease of labeling. He also limited the detail in his illustrations, instead focusing only on the components necessary to the aspect of the figure being studied. These minute changes aided in clarifying the message of the illustration and helped Buller to communicate the scientific concepts depicted. As Buller began teaching and developing his illustrations for students rather than just himself, he modified his own artistic style to create illustrations that would be better suited to communicating scientific knowledge to his students.

Buller believed that lectures should be kept extremely simple and easily intelligible.[294] The same is true for his wall charts, which have a simplified composition. In his wall chart depicting a common Sundew (*Drosera sp.*), a type of carnivorous plant leaf, I have noted that Buller copied much of the composition from botanist Albert Peter (1853-1937) and lithographer Emil Hochdanz's (1816-1885) "Droseraceae, Tafel 40" from the *Botanishe Wandtafeln* series (Figures 18 and 19).[295] However, to focus the students' attention on the feeding mechanism of the plant, Buller simplified Peter's wall chart by reproducing only one figure. He altered the composition by flipping the figure 180 degrees but otherwise remained faithful to the original, even reproducing the Peter's inconsistent shading under the stalked glands of the plant. Buller slightly altered the depiction of the fly on the Sundew leaf in an attempt to highlight this integral feature of the composition. The fly itself is the central component of the image as it demonstrates how the plant obtains nutrients, however Buller showed off his skill by painting the fly with translucent wings and he brightened the highlights from Peter's version to give the fly's body more volume and to attract students' attention to the fly.

[294] Estey, "A. H. R. Buller: Pioneer Leader in Plant Pathology," 21.

[295] The University of Manitoba Archives currently has 110 of the 120 wall charts in the series in its collection from Buller's holdings. Buller possibly owned *Tafel 40* and it has been destroyed or lost along with the other charts now missing from the set.

Another of Buller's wall charts is an ink and watercolor painting of various views of an ovulate pine cone (Figure 20). Buller maintains his practice of simple and straightforward compositions and again borrowed the form of his figures from another wall chart. He copied figures two, three, and four from the *Dodel-Port Atlas* Tafel 26 by the husband and wife team of botanist Arnold Dodel (1843-1908) and illustrator Carolina Port (*1856-?) (Figure 21). Although these three figures are very similar from the *Dodel-Port* wall chart, Buller's version is overall, markedly different. Buller simplified the chart to have only four illustrations versus Dodel-Port's nine. Additionally, each figure shares similarities to the original but Buller altered the style and composition to conform to his own. Buller also altered the composition to be read in a more logical manner than the *Dodel-Port Atlas* version. The image can be read from left to right beginning with two enlarged scales on the left-hand side. The top detail shows the top side of a scale with two ovules and the bottom detail depicts the underside of the scale. In the middle of the wall chart, a cross-section of the cone is show, depicting how the scales and ovules fit together. On the far right, Buller shows the female cone from the outside as it may be seen in nature. Composed in this way, Buller takes the student through the structure of the female Pine cone, showing the components of the cone and how they fit together. He also implemented a number of artistic techniques to make the image more comprehensible. Buller again used shading to help add volume to the figures of the scales and of the full cone, but on the cross-section he flattened and further simplified the image, leaving little more than an outline of the components being discussed.

It was not uncommon for scientists to create their own wall charts during this time period as many of the sets were designed for introductory lessons on physiology and systematics.[296]

[296] National Library of the Netherlands, "The Art of Knowledge: Educational Botanical Wallcharts 1879-1960 - The Heyday of Educational Wall Charts," *Memory of the Netherlands*.

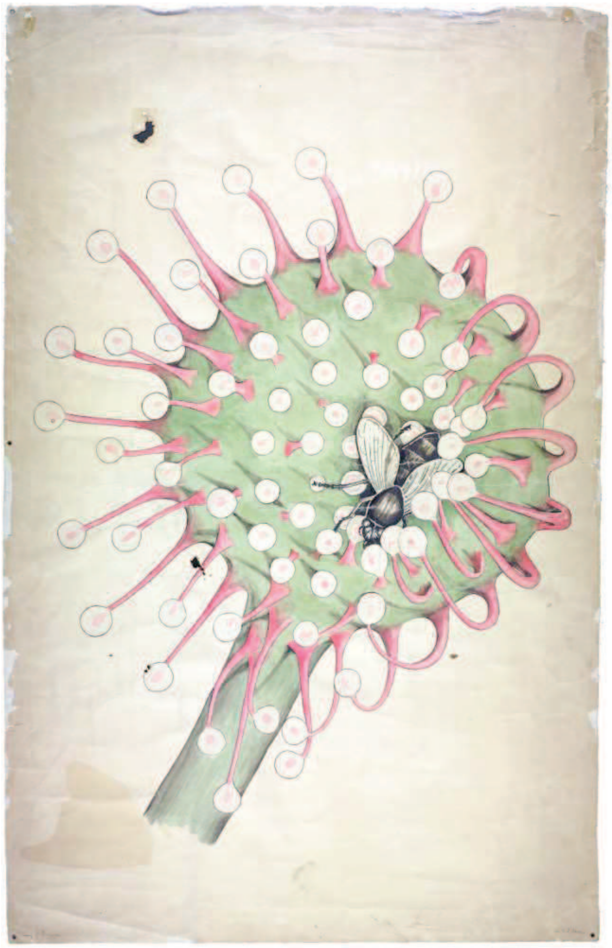

Figure 18. A.H. Reginald Buller, Untitled (Fly on *Drosera* Leaf), n.d.
UMA, Buller fonds, PC 175 (A.04-25)
Drawer 4, Folder 3, No. 1

Figure 19. Albert Peter, Droseraceae, Tafel 40, from the series *Botanishe Wandtafeln*, 1901. Collection of Stichting Academisch Erfgoed, Courtesy Memory of the Netherlands/Royal Library - National Library of the Netherlands

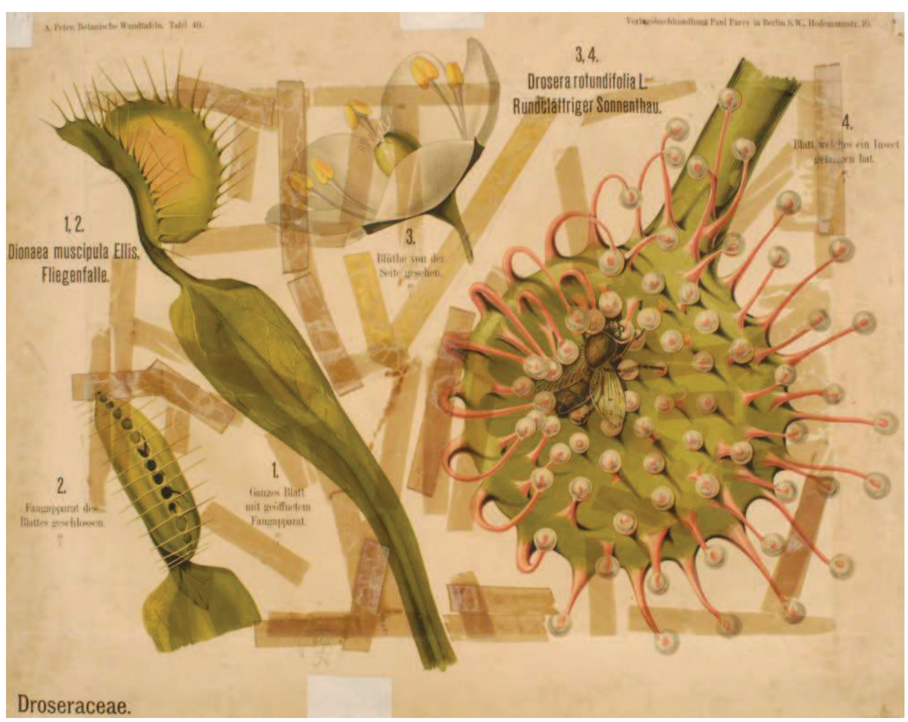

Figure 20. A.H. Reginald Buller, Untitled (Views of an ovulate pine cone), n.d., UMA, Buller fonds, PC 175 (A.04-25), Drawer 6, Folder 15, No. 4.

Figure 21. Arnold Dodel and Carolina Port, *Pinus Laricio var. austriaca,* from the series *Dodel-Port Atlas,* 1878-1893. Collection of Stichting Academisch Erfgoed, Courtesy Memory of the Netherlands/Royal Library - National Library of the Netherlands

Some laboratories went so far as to hire their own illustrators to create wall charts for their specific needs, but most of these hand-drawn wall charts were meant for higher level classes or to support the professor's new research.[297] Buller's watercolor wall charts do not fit this mold and are generally his own interpretations of common wall chart topics. All of Buller's wall charts conform to a simple and straightforward composition. He focused on the main goal behind the image and the students' ability to comprehend it. His choices in formal techniques exemplify Buller's consideration of how to manipulate his illustrations to covey his message. This creation of clearer and more concise illustrations was a direct result of Buller modifying his artistic style to better fit his pedagogy. These changes held true for his assistants as well, as every wall chart produced under Buller's direction maintains a very similar composition and style. Thereby, through the use of visual materials in his scientific work, specifically the use of wall charts, Buller was able to disperse new botany principles in his classroom.

Buller was a science communicator which required him to make difficult decisions about the form his visual reproductions would take and the function they would have in disseminating and explaining scientific knowledge.[298] Even small alterations to an image can greatly affect its impact and message. Visual representations are thought to be processed in the brain differently than written language.[299] Images may even processed similarly to experiences, allowing a viewer to react emotionally to a visual representation before fully comprehending the image.[300] Therefore, the role of the science communicator is particularly important as they teach the

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[297] National Library of the Netherlands, "The Art of Knowledge: Educational Botanical Wallcharts 1879-1960 - The Heyday of Educational Wall Charts," *Memory of the Netherlands*.

[298] Trumbo, "Making Science Visible," 276.

[299] Ibid.

[300] Ibid.

student to interpret the language of the discipline's visual representation properly.[301] Once a student learns the language of visual representation for their discipline, they are better equipped to read other images on their own, even outside of their discipline.

Although Buller purchased wall charts for teaching, he supplemented them with designing and painting his own from 1904 onward.[302] In an effort to construct wall charts to emphasize the image, they had little to no labeling. Further simplifying, Buller's watercolor wall charts limited the included text even more. The lack of labeling forced the student to read the image on display rather than being distracted by text. However, students as non-experts, may not yet be able to fully comprehend a visual representation without the help of the scientist.[303] Buller, the science communicator, had to explain the concepts related to the wall chart, allowing the non-expert students learn the visual language of botany.[304] Nevertheless, wall charts were a great asset in the classroom because such visual aids helped students from various backgrounds and levels better grasp the material.[305] With the expansion of the educational systems across the Western world, more students enrolled and attended classes.[306] Therefore classrooms were filled with students from a wide range of learning backgrounds. Wall charts were helpful for those students that may not have had a strong verbal literacy or that did not fluently speak the language in which the class was being taught. Visual literacy differs from verbal literacy in that it requires

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[301] Trumbo, "Making Science Visible," 276.

[302] Buller, "Report on the Botanical and Geological Departments 1904-1905," 9.

[303] Trumbo, "Making Science Visible," 276.

[304] Ibid.

[305] Margaret Maria Olszewski, "Dr. Auzoux's Botanical Teaching Models and Medical Education at the Universities of Glasgow and Aberdeen," *Studies in History and Philosophy of Biological and Biomedical Sciences* 42, no. 3 (2011) 295.

[306] Erik Zevenhuizen, "Uit de Drukpers En van de Tekentafel: Botanische Onderwijsplaten van Nederlandse Universiteiten" (University of Amsterdam, 2005),

less time to learn.[307] Even to non-experts and students, many visual reproductions are comprehensible on a basic level.[308] To get the full meaning from an image, however, comprehending the visual language of the disciple is imperative. Wall charts still required a professor to interpret and engage the students with the content.[309]

The direction Buller took to simplify his own wall charts was unique compared to the lithographed sets available. A critique of the lithograph sets was that they were too cluttered.[310] When compared to charts that were considered to be less cluttered, like *Tabulae Botanicae* or the later *Jurica Biology Series,* Buller's charts are considerably more simplified and clear. Comparing again to one of Buller's first inspirations, Ernst Haeckel, Buller's works are even more simplified. Haeckel's illustrations are decorative with many organisms per page and his link to Art Nouveau is evident. In contrast, Buller's illustrations are much cleaner, with only a few figures per chart and each figure lightly outlined. Buller eliminated all extraneous detail and utilized natural colors and simplified forms in his illustrations. In contrast to Haeckel, Buller's artistic style is influenced by the Arts and Crafts movement.

Buller's personal library held a handful of art books, including one on art appreciation and three by renowned art critic and theorist John Ruskin (1819-1900).[311] Although most remembered for art criticism, Ruskin was also interested in science and discussed geology and botany in his writings. Ruskin was influential to several prominent artists for his theory that

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[307] Trumbo, "Making Science Visible," 277.

[308] Ibid.

[309] Bucchi, "Images of Science in the Classroom," 189.

[310] Charles E. Bessey, "Botanical Notes," *Science* 27, no. 691 (1908) 514.

[311] Buller's Ruskin collection included his autobiography *Praeterita: Outlines of Scenes and Thoughts Perhaps Worthy of Memory in my Past Life,* his popular set of lectures on education and gender, *Sesame and Lilies: Three Lectures,* and his essay on the principles of architecture, *The Seven Lamps of Architecture.* Johnson, *Catalogue of the Buller Memorial Library,* 79.

artists should find forms for their work from nature and he helped spur the Arts and Crafts movement with the concept that art should be both beautiful and utilitarian.[312] Interestingly, Ruskin was also a vociferous critic of Darwinian evolution.[313] Smith argues that Ruskin's distaste for Darwin's theories is because through evolution, concepts of the "human aesthetic sense" and ideals of beauty are mere inheritances rather than gifts from God or signs of morality.[314] Ruskin was religious and believed that man's innate imperfection stemmed directly from the Fall from Grace, resulting in imperfect creations which were "better, lovelier, and more beloved for the imperfections which have been divinely appointed."[315]

Clearly Buller did not agree with Ruskin's refutation of Darwinian evolution as evidenced by his discussion with Rev. Drummond in the editorials of the *Manitoba Free Press* in 1904, as well as the portrait of Darwin hanging in his office.[316] This notwithstanding, Ruskin's concepts of nature in art may have appealed to Buller, as there are similarities between his wall charts and Arts and Crafts designs. While teaching art classes at Oxford University Ruskin used many botanical examples. He instructed students to not simplify illustrations of plants, but rather make them "graceful" and to include seeming imperfections stating, "in fine design, there are

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[312] H. H. Arnason and Peter Kalb, *History of Modern Art: Painting, Sculpture, Architecture, Photography*, 5th ed. (Upper Saddle River, N.J.: Prentice Hall, 2003) 82. There is a well-developed literature on Ruskin and his theories which will not be discussed here. Smith's *Charles Darwin and Victorian Visual Culture* offers an insightful analysis of the aesthetics of the era.

[313] Smith, *Charles Darwin and Victorian Visual Culture,* 2.

[314] Ibid., 3.

[315] Clive Wilmer, "'No Such Thing as a Flower [...] No Such Thing As A Man': John Ruskin's Response to Darwin," in *Darwin, Tennyson and Their Readers: Explorations in Victorian Literature and Science*, ed. Valerie Purton (New York: Anthem Press, 2013) 99-100.

[316] Goldsborough, "Reginald Buller," 23.

local uncouthnesses, as, in fine music, discords."[317] This concept opposes truth-to-nature and falls more closely to trained judgement.

The Arts and Crafts movement originated in Great Britain in the 1880s and quickly gained popularity, spreading across North America.[318] Birmingham, Buller's hometown, was a center of Arts and Crafts art and architecture and many of the city's elite believed in Ruskin's theories.[319] The city was also the birthplace of one of the movement's key figures, Edward Burne-Jones (1833-1898). Burne-Jones befriended artist William Morris (1834-1896) while at school at Oxford University and both were largely influenced by Ruskin's writings.[320] The two then founded the Morris & Co. design studio which was a leader of the Arts and Crafts movement.[321] Birmingham remained a hotbed of the Arts and Crafts movement as Burne-Jones was active in the area, designing stained glass for churches.[322] Arts and Crafts inspired artists were frequently invited to exhibit in the city and William Morris visited several times to speak.[323] Buller was inspired by the theories and designs of Burne-Jones and William Morris, and implemented many of the Arts and Crafts movement's tenets into his own illustrations.

The Arts and Crafts movement was largely a reaction against the mass-produced products and highly ornate patterns of the day. The designs of the movement emphasized natural forms

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[317] John Ruskin, "Ashmolean: The Elements of Drawing, John Ruskin's Teaching Collection at Oxford," 2013, http://ruskin.ashmolean.org/collection/8990/9164/9173/13814.

[318] Arnason and Kalb, *History of Modern Art,* 75.

[319] Sian Everitt, "Birmingham Institute of Art and Design," *Birmingham Institute of Art and Design*, http://fineart.ac.uk/institutions.php?idinst=9.

[320] Judith Flanders, "The Last Pre-Raphaelite: Edward Burne-Jones and the Victorian Imagination by Fiona MacCarthy: Review," September 12, 2011, sec. Culture.

[321] Flanders, "The Last Pre-Raphaelite."

[322] Everitt, "Birmingham Institute of Art and Design."

[323] Norman Kelvin and William Morris, *William Morris on Art and Socialism* (New York: Dover Publications, 1999) iii.

and colors, and preferred traditional modes of craft, such as wood block prints. Buller created aesthetically pleasing, yet utilitarian, wall charts that emphasized simple compositions using preindustrial techniques. Buller's artistic work utilized similar natural colors and simplified forms prevalent in the Arts and Crafts style. Despite this, Buller was not part of the art circles in England or in Manitoba. He did not seek out prominent artists of the area or attend exhibition openings. While it is doubtful that Buller was intimately aware of the intricacies of the art world, he was a visual thinker and highly aware of the images around him.[324] Buller was living in England and Germany during the height of the Arts and Crafts movement and its natural motifs may have appealed to him. He also would have picked up on the bold, clean lines, and simplified forms of Arts and Crafts art, design, and advertisements that had appeared in England and Germany since the 1880s and applied these concepts to his own artistic style.

In comparing Buller's wall chart from the early twentieth century of *Smilax aspera* (Figure 22), a thorny vine, to William Morris's design in wood block print for his *Trellis* (Figure 23) wallpaper from 1862, similarities appear. *Trellis* was the first wallpaper that Morris designed and it was inspired by the Medieval-style garden at his home.[325] Morris' print depicts a simplified rose weaving up a perfectly square trellis system. Morris drew the trellis and rose himself but asked his colleague Philip Webb to create the birds for the design.[326] Similar to Buller's *Smilax aspera* illustration, the plant in Morris' design is thickly outlined in black, which flattens the image by defining its shape. Buller attempted some shading and highlighting in his

[324] Visual thinking can be defined as the way in which we process images and comprehend them as well as the meaningful incorporation of images into thought. Trumbo, "Making Science Visible," 269.

[325] Gregory Herringshaw, "Trellis by William Morris," *Cooper Hewitt Smithsonian Design Museum*, 2016, https://www.cooperhewitt.org/2016/08/26/trellis-by-william-morris/.

[326] "Trellis by William Morris," *Victoria and Albert Collections*, 2017, http://collections.vam.ac.uk/item/O78220.

illustration, but the effect is outweighed by the outline and lack of background. The use of color in both works is also similar, as both artists use natural, muted colors. Additionally, the use of line between is comparable as both artists use confident strokes to create strong and graceful forms - as Ruskin would have approved. Both compositions, however, have been altered from nature to fit their uses. Morris' rose, although botanically accurate, is highly stylized, while Buller's *Smilax aspera* is simplified and shows only part of the plant omitting flowers and berries.

Buller manipulated his own artistic style to better fit his pedagogy, creating more clear and concise illustrations. Even when borrowing figures from mass-produced wall charts he would alter the composition and details to ensure that the finalized chart would conform to his charts and ideals. Through the use of visual materials in his scientific work, Buller was able to disperse new botany principles in his classrooms. By creating his own wall charts, Buller was carrying on the legacy of other significant botanical scientist-artists who emphasized the use of visual materials in their classrooms. However, Buller was working during the end of botany's "Golden Age" of popularity. By the end of World War I, botany classes were being dropped from schools and amalgamated into biology programs.[327] However, due to his creative use of visual materials and engaging lectures, Buller maintained student interest in the University of Manitoba botany program, keeping enrollment high throughout his tenure.

Buller was an internationally renowned scientist who modernized botanical knowledge on the Canadian prairies. Along with his colleagues, Buller brought the world's attention to Winnipeg's mycological research.[328] By utilizing botanical wall charts, both mass-produced

[327] Stanley Norris, "Canadian Biology Teaching: An Historical Perspective," *The American Biology Teacher* 27, no. 8 (1965) 613.

[328] Estey, *Early History of Plant Pathology,* 277.

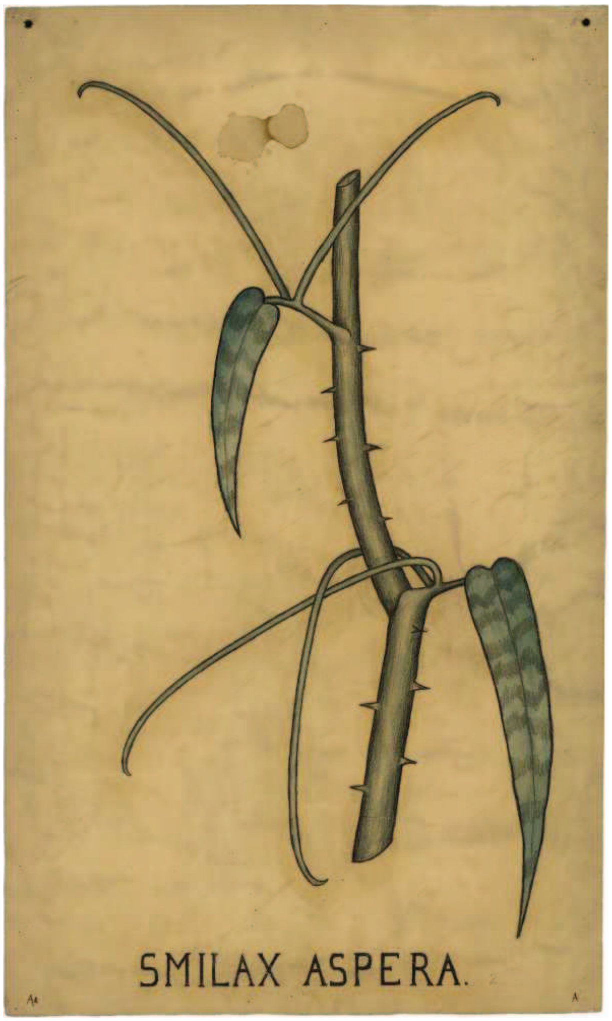

Figure 22. A.H. Reginald Buller, *Smilax aspera,* n.d.
UMA, Buller fonds, PC 175 (A.04-025)
Drawer 4, Folder 26, No. 4

Figure 23. William Morris and Philip Webb, *Trellis* wallpaper, 1864.
© Victoria & Albert Museum, London, E.452-1919.

and hand illustrated, Buller also introduced new teaching methodologies to Western Canada. While botany was generally criticized by students for being a dry and boring subject, Buller was lauded for his captivating style. He gained a reputation as an engaging teacher and through researcher, attracting students from around North America to work with him. Enrollment under Buller swelled past room capacity.[329] While Canada was a young growing nation, Buller help to cultivate its scientific community through education utilizing a combination of New Botany methodologies and visual learning. He not only demonstrated the new world of modern botanical science but a whole new way of visualizing the natural world.

[329] Goldsborough, “Reginald Buller," 22.

Conclusion

Dr. Reginald Buller was an important figure in the creation of a scientific community in Manitoba. He helped break down some of Winnipeg's isolation by tying the city to the international scientific community and building connections with international societies, like the BAAS. He maintained close ties with his English friends and colleagues, regularly returning to Kew and the University of Birmingham in the summer, as well as speaking at universities in the United States and England, which further extended his and the University of Manitoba's presence abroad. More significant was Buller's contribution to the science educational community in Manitoba, which was influenced by his training in New Botany techniques developed in Germany. Previously, the province's science education had been handled mainly by clergy at small colleges, but with the creation of the University of Manitoba and the hiring of Buller, botanical education was transformed from natural theology and natural philosophy to secular modern practice.

As noted throughout my discussion, wall charts are interesting, multi-disciplinary objects that deserve in-depth examination as they have gone unacknowledged by scholars and cultural institutions. Further research is required to give insight into the rare perspective of their unique intersection of art, science, and education.[330] They act not only as education aids but also as aesthetic objects with meaning of their own. Visual aids allowed scientists to communicate knowledge. Such visual materials, namely lithograph and watercolor wall charts were essential components to Buller's pedagogical practice. Buller's charts were unique in that they were created for all levels of post-secondary scholarship and that they were modified to fit his own needs.

[330] Jones and Galison, eds., *Picturing Science Producing Art*. 6.

Buller was acutely aware of the power of visual representations and crafted his charts carefully to ensure that his message was transferred as accurately as possible. His adaptation of the Arts and Crafts style in his charts and visual aids led to the creation of interesting and entertaining lectures that he became well known for. Buller's unique status as a scientist-artist formed a singular pedagogy that revolutionized the flow of botanical knowledge through the University of Manitoba and throughout Canada.

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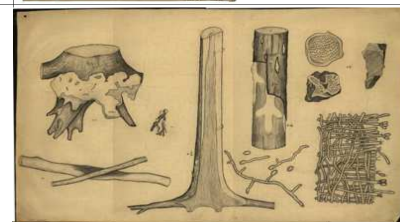
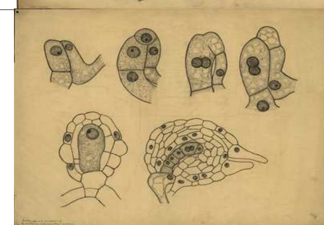
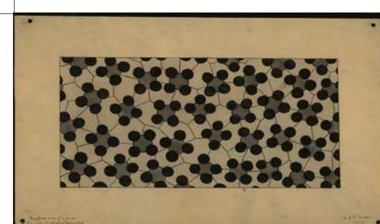
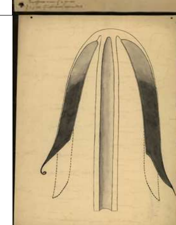
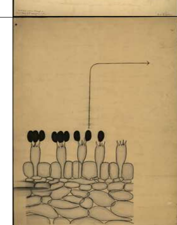
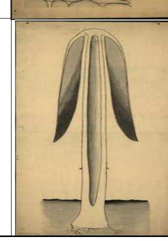
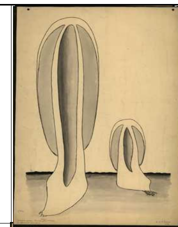
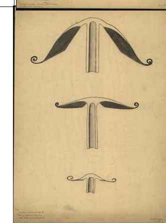
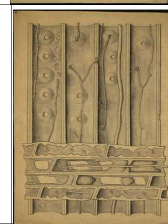
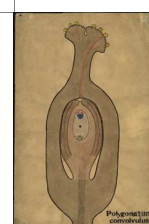
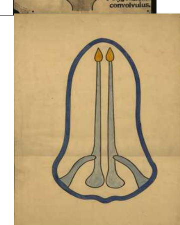
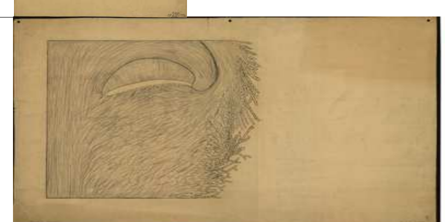
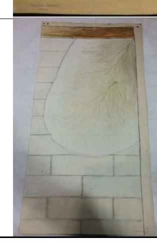
Appendix: Draft Chart of Buller's Watercolor Wall Chart Collection

The following chart was compiled from the University of Manitoba Archives and Special Collections website, several lists provided by the Archives, and my own research. I made all noted attributions and photographs were from the University of Manitoba Archives or taken my me. This chart should be used as a draft document as a complete cataloguing effort for the wall chart collection is still required.

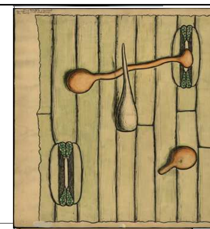
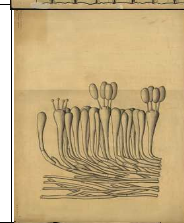
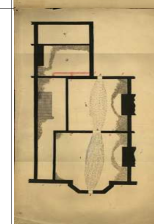
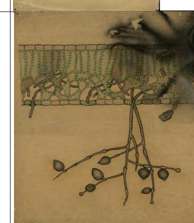
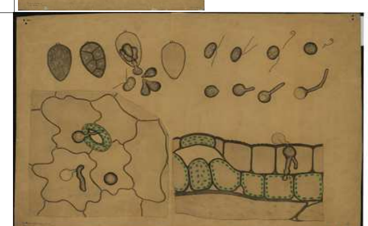
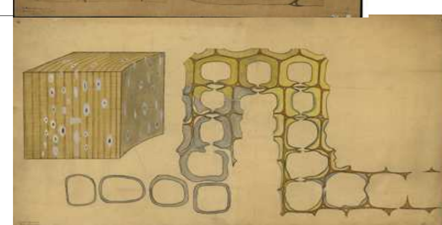
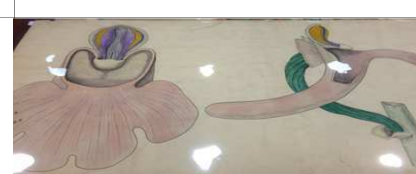
Buller's Watercolor Wall Charts

title	artist	date	source	acc. no.	images
Orchis mascula: From Marshal's Letters on Evolution with riotellum altered. Made for Miss Rioch's lecture on Orchids	Buller, A.H.R.	May 1919	Charles Darwin - Fertilization of Orchids (p. 8)	A.04-025.004.0026.013.0001	
Fomes annosus (Trameres radiciperda)	Buller, A.H.R.		Hartig	A.04-025.006.0006.008.0001	
Fertilization and development of the perithecium of Sphaerotheca casragnei	Buller, A.H.R.		Strasburger	A.04-025.003.0007.002.0001	
Leaf shapes	Buller, A.H.R.				
Surface view of a piece of a gill of Coprinus comatus	Buller, A.H.R.	1909		A.04-025.006.0006.007.0001	
Vertical section through a fruit body of C. comatus after autodigestion has begun	Buller, A.H.R.	1909		A04-025.006.0006.009.0001	
Section through the hymenium of C. comatus in the region of spore discharge	Buller, A.H.R.	1909		A.04-025.006.0006.005.0001	
Vertical section through a ripe fruit body of Coprinus comatus	Buller, A.H.R.	1909		A.04-025.006.0006.012.0001	

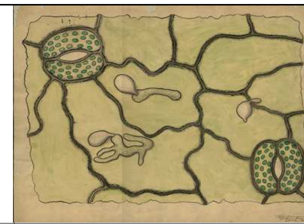
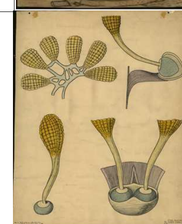
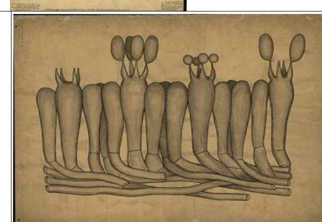
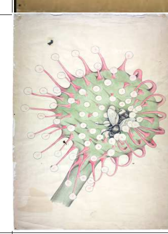
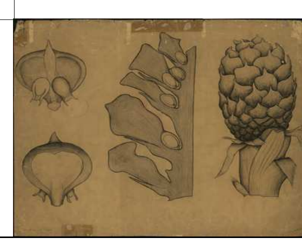
Buller's Watercolor Wall Charts

Vertical section through young fruit bodies of Coprinus comarus	Buller, A.H.R.	1909		A.04-025.006.0006.004.0001		
Vertical sections through the Pilei of Coprinus comatus in last stages of autodigestion	Buller, A.H.R.	1909		A.04-025.006.0006.010.0001		
R. L. S. of wood of Pine from a rotten paving block showing hyphae of Lentinus lepideus	Buller, A.H.R.			A.04-025.006.0006.011.0001		
Upon the number of Micro-Organisms in the air of Winnipeg	Buller, A.H.R.	1911	Buller & Lowe - Upon the number of Micro-Organisms in the air of Winnipeg, by A. H. R. B. & Chas. W. Lowe from Transactions of the Royal Society of Canada			
Polygonatum convolvulus during pollination	Buller, A.H.R.		Strasburger	A.04-025.006.0002.001.0001		
Salvia: Mouth of flower showing motile stamens	Buller, A.H.R.	Apr 1916		A.04-025.004.0026.027.0001		
Agaricus melius	Buller, A.H.R.		Hartig	A.04-025.006.0006.003.0001		
Growth on brick wall	Buller, A.H.R.					

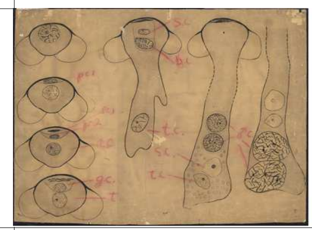
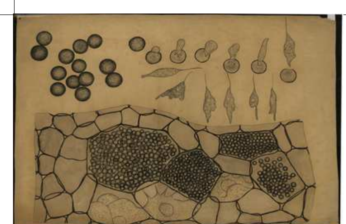
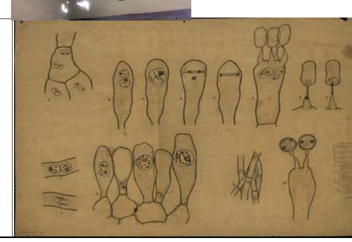
Buller's Watercolor Wall Charts

Aedides spores from a Barberry leaf germinating on the epidermis of a wheat leaf	Buller, A.H.R.	c. 1916		A.04-025.004.0026.003.0001		
Basidia and paraphyses - Lentinus lepidius	Buller, A.H.R.			A.04-025.006.0006.002.0001		
Ventilation for dry-rot infected house	Buller, A.H.R.			A.04-025.003.0008.001.0001		
Sporangiophores of Phytophthora infestans	Buller, A.H.R.			A.04-025.004.0026.017.0001		
Zoospore formation and germination of Phytophthora infestans	Buller, A.H.R.			A.04-025.006.0015.002.0001		
Destruction of wood by Fomes annosus (Trametes radiciperda)	Buller, A.H.R.		Hartig	A.04-025.003.0007.001.0001		
Salvia - Bee visiting flower	Buller, A.H.R.		Kerner & Oliver			
Orchis mascula- Made for Miss Rioch's lecture on orchids	Buller, A.H.R.	May 1919	Marshal - Lectures on Evolution	A.04-025.004.0008.001.0001		

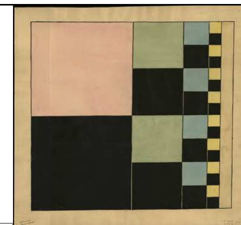
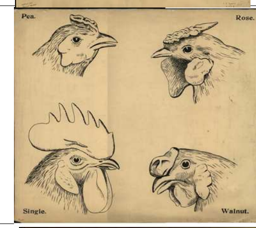
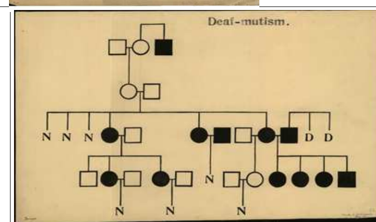
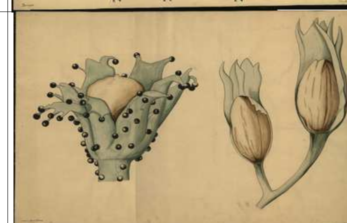
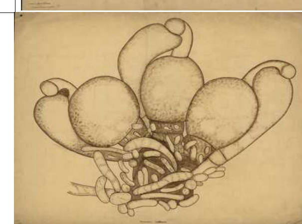
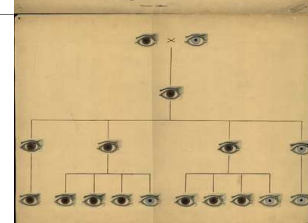
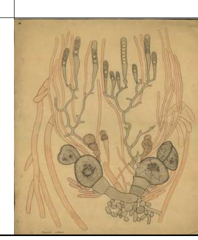
Buller's Watercolor Wall Charts

Basidiospores or sporidia of Puccinia graminis germinating on a Barberry leaf	Buller, A.H.R.	c. 1916		A.04-025.004.0026.021.0001		
Scheme to illustrate pollination & fertilization diagramatically	Buller, A.H.R.	Sep 1905				
Germination of spores of mushroom	Buller, A.H.R.		Duggar?	A.04-025.006.0013.001.0001		
Orchis Mascula - Made for Miss Rioch's Lecture on orchids	Buller, A.H.R.	Mar 1919	Darwin - Fertilization of Orchids (pg. 8)	A.04-025.004.0026.029.0001		
Section through the hymenium of Polyporus squamosus	Buller, A.H.R.	1909		A.04-025.006.0012.001.0001		
Leaf of Drosera	Buller, A.H.R.			A.04-025.004.0003.001.0001		
Caption illegible	Buller, A.H.R.	1916				
Female cone of Pinus	Buller, A.H.R.			A.04-025.006.0015.004.0001		

Buller's Watercolor Wall Charts

Funaria Hygrometrica	Buller, A.H.R.			A.04-025.006.0015.006.0001		
Salvia	Buller, A.H.R.	Apr 1916	Kerner - Mechanical Diagram			
Stages in the growth of part of a of Pinus	Buller, A.H.R.	May 1902		A.04-025.004.0005.001.0001		
V. T. S. gills of Psalliota campestris showing sporabolas	Buller, A.H.R.	1909				
Puccinia araminis on Wheat	Buller, A.H.R.	1916				
Plasmodiophora brassicae	Buller, A.H.R.		Marshall Ward	A.04-025.006.0007.001.0001		
Floral diagrams of Orchidaceae… - For Rioch's lecture	Buller, A.H.R.	Mar 1919	Pflanzenfamilian			
Nuclear division and spore formation: Hymenomycetes & Gasteromycetes	Buller, A.H.R.		Ruhland Bot. Zeit. 1901 Iabt. Heft X.	A.04-025.006.0010.001.0001		

Buller's Watercolor Wall Charts

Galton's Law - Thomson's "Heredity"	Buller, A.H.R. & Brownlee, T.I.		Thomson - Heredity	A.04-025.005.0003.013.0001		
Roosters	Buller, A.H.R. & Churchward, Stanley G.	Nov 1919	Punnett	A.04-025.005.0003.003.0001		
Deaf-mutism	Churchward, Stanley G.	Dec 1912	Davenport	A.04-025.005.0003.009.0001		
Seeds of Cycadofilices	Churchward, Stanley G.	Oct 1912	Coulter, Barnes & Cowles	A.04-025.006.0015.008.0001		
Pyronema confluens	Churchward, Stanley G.	1912	Harper - "Sexual Reproduction in Pyronema" from Annals of Botany (vol XIV p. 321)	A.04-025.004.0026.030.0001		
Inheritance of Eye Pigment (Original and Schematic)	Churchward, Stanley G.	1912		A.04-025.005.0003.006.0001		
Varying positions taken by chlorophyll corpuscles in the cells of Lemma trisulca in illuminations of different intensity	Churchward, Stanley G.	1911	Strasburger			
Pyronema confluens	Churchward, Stanley G.	1912	Haper - "Sexual Reproduction in Pyronema" from Annals of Botany (vol XIV p. 321)	A.04-025.004.0026.023.0001		

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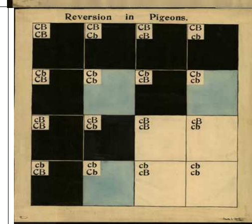
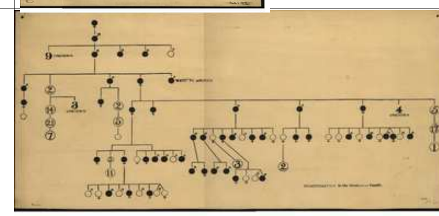
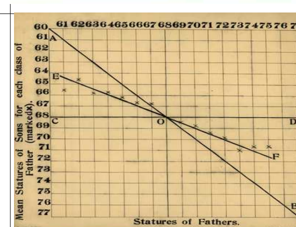
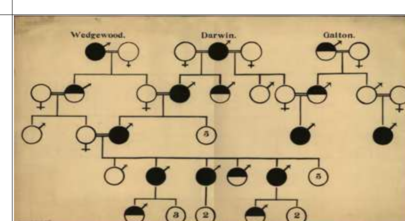
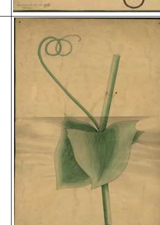
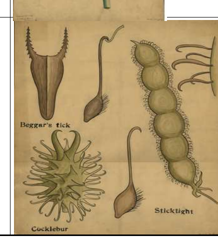
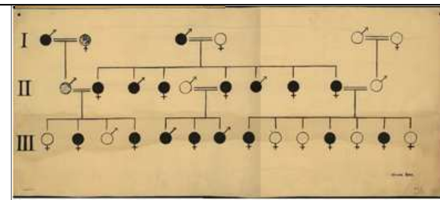
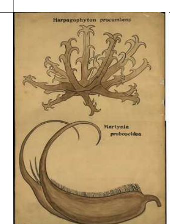
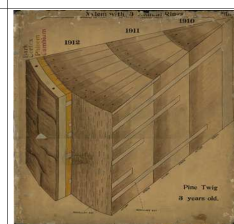
Seeds of Pecopteris	Churchward, Stanley G.	Oct 1912	Coulter, Barnes & Cowles	A.04-025.006.0015.0070001		
Reversion in Pigeons	Churchward, Stanley G.	Nov 1912	Punnett	A.04-025.005.0003.012.0001		
Brachydactyly in the Drinkwater Family	Churchward, Stanley G.	1912	Bateson	A.04-025.005.0003.014.0001		
Statures of Fathers - Correlation Coefficient	Churchward, Stanley G.	Dec 1912	Doncaster - Statures of Fathers	A.04-025.003.0005.001.0001		
Dihybridism in seeds of Pisum (Original & Schematic)	Churchward, Stanley G.	1912				
Inheritance of Scientific Ability	Churchward, Stanley G.	Dec 1912	Whetham	A.04-025.005.0003.001.0001		
Metamorphosis of leaf of Lathyrus aphaca	Churchward, Stanley G.	1911	Strasburger	A.04-025.006.0001.001.0001		
Hooked Fruits: Beggar's Tick, Cocklebur, Sticktight	Churchward, Stanley G.	Mar 1915		A.04-025.004.0026.025.0001		

Buller's Watercolor Wall Charts

Brown Eyes	Churchward, Stanley G.	1912	Whetham	A.04-025.005.0003.016.0001		
Untitled (Transpiration)	Churchward, Stanley G.	1919	Detmer (Fig. 86)	A.04-025.004.0026.014.0001		
Andalusian fowls	Churchward, Stanley G.	Nov 1912	Darbshire			
Linnean system of classification	Churchward, Stanley G.	Oct 1912	Kerner & Oliver			
Harpagophyton procumbens - Hooked Fruits	Churchward, Stanley G.	Mar 1915	Lubbock	A.04-025.005.0003.005.0001		
T. S. Guard Cells of Stoma	Churchward, Stanley G.	1912				
Tendrils of Echinocystis lobata	Churchward, Stanley G.	1914		A.04-025.004.0026.018.0001		
Ash constituents of plant organs	Churchward, Stanley G.	1911	Strasburger			

Buller's Watercolor Wall Charts

Placentation	Churchward, Stanley G.	1915				
Diabetes insipidus heredity chart	Churchward, Stanley G.					
Xylem with 3 annual rings	Churchward, Stanley G.			A.04-025.006.0005.002.0001		
Germination of Date	Churchward, Stanley G.	1912	Sachs			
Tuberous of Dahlia	Churchward, Stanley G.	Nov 1914	Gray	A.04-025.006.0005.005.0001		
Strobilus of Cycadeoridea	Churchward, Stanley G.	Oct 1912	Coulter, Barnes & Cowles	A.04-025.006.0005.001.0001		
Original	Churchward, Stanley G.	Oct 1912				
Scheme to illustrate gametic segregation	Churchward, Stanley G.	Oct 1912	Punnett (2nd Ed.)			

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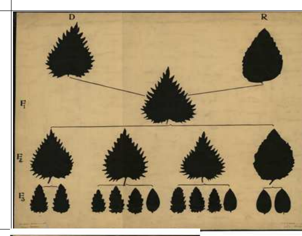
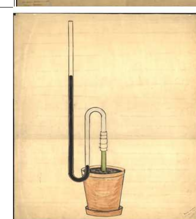
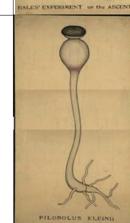
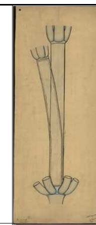
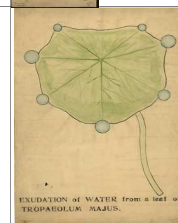
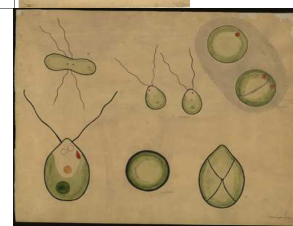
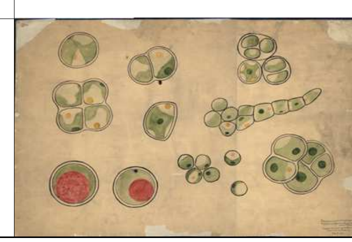
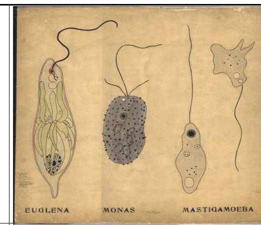
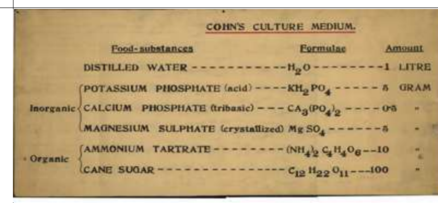
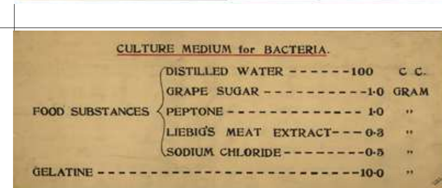
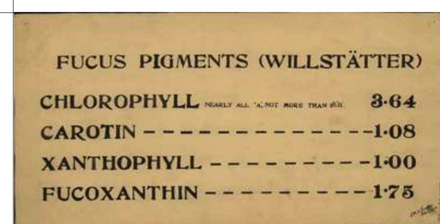
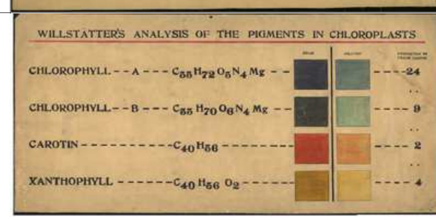
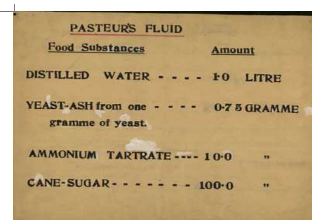
"Red Snow" - Sphaerella nivolis	Churchward, Stanley G.	Mar 1913	Kerner & Oliver (Pl. 1: Sphaerella nivolis)	A.04-025.004.0022.001.0001		
Knight's Wheel, 1806	Churchward, Stanley G. & Tanton, F.M.S.	1915				
From Darbishire Pea Plant	Churchward, Stanley G. and Brownlee, T.I.	Nov 1912				
Mendelian phenomena in nettles	Churchward, Stanley G. and Brownlee, T.I.	Nov 1912	Thomson - Heredity	A.04-025.005.0005.001.0001		
Dahlia variabilis: Root pressure	Lowe, Charles	Jun 1908	Strasburger (Fig 76)	A.04-025.004.0026.008.0001		
Hale's Experiment on the Ascent of Sap in Wood	Lowe, Charles	Jan 1908	Strasburger	A.04-025.004.0026.032.0001		
Pilobolus Kleinii	Lowe, Charles	Feb 1910		A.04-025.006.0006.006.0001		
Microorganisms of the Air of Winnipeg	Lowe, Charles	Aug 1909	Buller & Lowe - Upon the number of Micro-Organisms in the air of Winnipeg, by A. H. R. B. & Chas. W. Lowe from Transactions of the Royal Society of Canada			

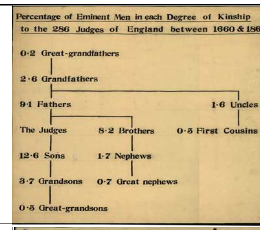
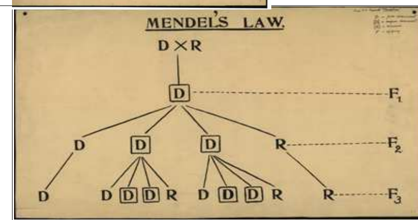
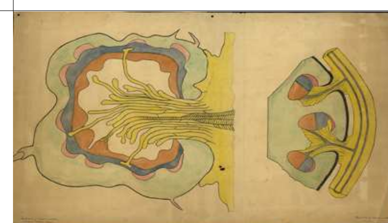
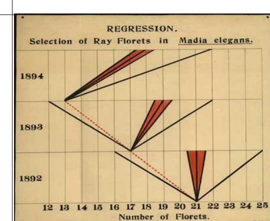
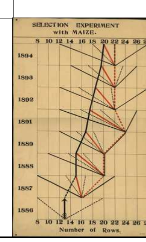
Buller's Watercolor Wall Charts

To illustrate Plasmolysis - Nitella	Lowe, Charles	Feb 1919	Strasburger	A.04-025.004.0026.009.0001		
Exudation of water from a leaf of Tropaeolum majus	Lowe, Charles	Jan 1908	Strasburger	A.04-025.003.0001.001.0001		
Chlamydomonas	Lowe, Charles	Feb 1923		A.04-025.006.0006.001.0001		
Tensile Strength	Lowe, Charles	Feb 1910	Haberlandt			
Drawings of plant stems	Lowe, Charles	1916				
Root hair in soil	Lowe, Charles	Jan 1908				
Plasmolysis	Lowe, Charles	c. Feb 1910	Vine - Physiology of Plants			
Protococcus viridis (Chloroplast pigments and nucleus) and Protococcus rufescenss v. sanguiniumwith red pigment Adapted from West's Algae and from Observation by C.W. Lowe	Lowe, Charles	Feb 1923	West - Algae	A.04-025.004.0010.001.0001		

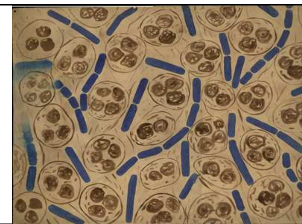
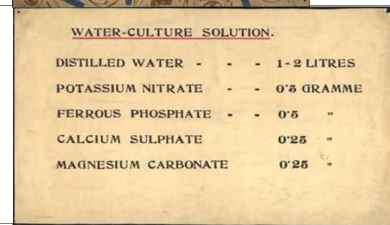
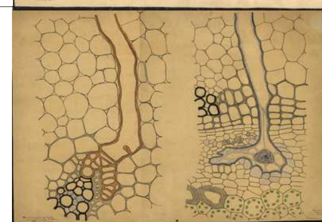
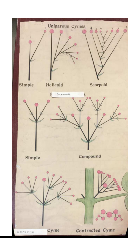
Buller's Watercolor Wall Charts

Euglena, Monas, Mastigamoeba	Lowe, Charles; Churchward, Stanley G.	Dec 1915	M. imrtens (Krebs) Die habur Pflung Fig 72; M. viripara Ebbr. Die habur Eflang Fig 88; E. viridis Ehbs after Semmo Wager Harti Pflang Fig 126 and Wager Eyespot Flagellum of E. vividis Fig 2. (can't read this at all!)	A.04-025.004.0023.001.0001		
Darlingtonia	Lowe, Charles (attributed to)	1906				
Cohn's Culture Medium	Tanton, F.M.S.			A04-025.004.0026.012.0001		
Culture Medium for Bacteria	Tanton, F.M.S.	Jan 1916	Buller & Lowe - Upon the number of Micro-Organisms in the air of Winnipeg, by A. H. R. B. & Chas. W. Lowe from Transactions of the Royal Society of Canada	A.04-025.003.0007.003.0001		
Fucus pigments (Willstatter)	Tanton, F.M.S.	Feb 1916	Jorgensen & Stiles - Carbon Assimilation in New Phylologist (No. 809 Vol. XIV, Oct-Nov 1915)	A.04-025.004.0026.001.0001		
Willstatter's Analysis of the Pigments in Chloroplasts	Tanton, F.M.S.	Jan 1916	Jorgensen & Stiles - Carbon Assimilation in New Phylologist (No. 809 Vol. XIV, Oct-Nov 1915)	A.04-025.004.0014.001.0001		
Pasteur's Fluid	Tanton, F.M.S.	Dec 1915		A.04-025.004.0026.011.0001		
No. of Micro-organisms falling on 1 square foot per minute						

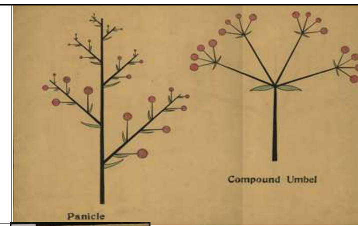
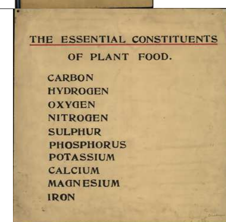
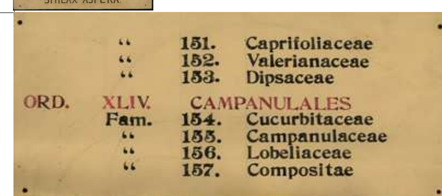
Buller's Watercolor Wall Charts

<table>
<tr><td>Percentage of Eminent Men in Each Degree of Kinship to the 286 Judges of England Between 1660 and 1865</td><td></td><td></td><td></td><td>A.04-025.005.0003.008.0001</td><td>
</td><td></td></tr>
<tr><td>Mendel's Law</td><td></td><td></td><td>R. C. Punnett - Mendelism</td><td>A.04-025.005.0003.007.0001</td><td>
</td><td></td></tr>
<tr><td>List of Species Orders XXXIV-XLIII</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Haustorium of cuscuta europaea in stem of Urtica divica</td><td>Buller, A.H.R. (attributed to)</td><td></td><td>Haberlandt (Haustorica of Cuscuta europaea in stem)</td><td>A.04-025.004.0026.031.0001</td><td></td><td></td></tr>
<tr><td>Head of tentacle of Drosera</td><td></td><td></td><td>Darwin</td><td></td><td></td><td></td></tr>
<tr><td>Regression: Selection of Ray Florets in Madia elegans</td><td></td><td></td><td>De Vries</td><td>A.04-025.005.0003.011.0001</td><td>
</td><td></td></tr>
<tr><td>Floral diagrams of wheat & ? - Made for the first popular lecture in Botany - About 1907</td><td></td><td>ca. 1907</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Selection Experiment with Maize</td><td></td><td></td><td>De Vries</td><td>A.04-025.005.0003.010.0001</td><td>
</td><td></td></tr>
</table>

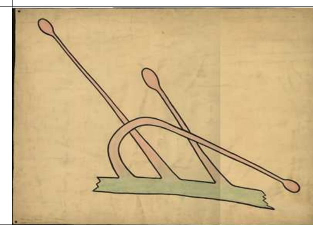
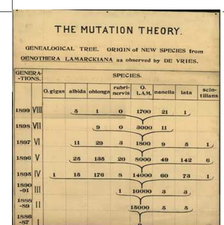
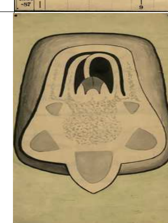
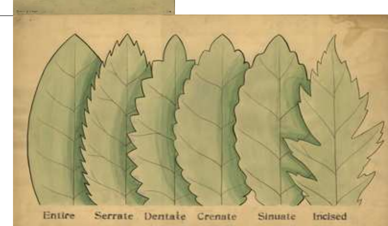
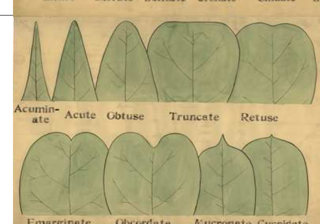
Buller's Watercolor Wall Charts

Bacillus anthracis	Lowe, Charles (attributed to)			A.04-025.003.0007.004.0001		
Water-Culture Solution			Strasburger	A.04-025.004.0026.010.0001		
Haustorium thread of Cuscuta europea growing into vascular bundles of Urtica diorca	Buller, A.H.R. (attributed to)		Haberlandt (Fig. 2: Haustorium thread in second?)	A.04-025.004.0026.006.0001		
Bacillus tuberculosis	Lowe, Charles (attributed to)			A.04-025.003.0007.005.0001		
List of Species Angiospermae						
List of Species Angiospermae, Order V-XII						
List of Species Dicotyledoneae Orders XIII-XXVI						
Uniparous Cymes	Churchward, Stanley G. (attributed to)					

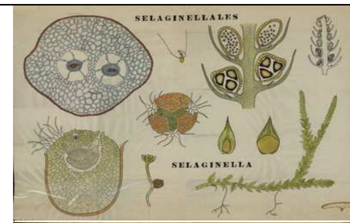
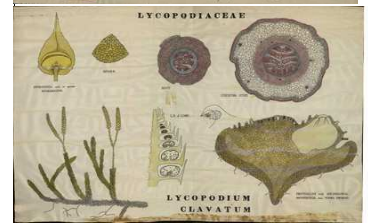
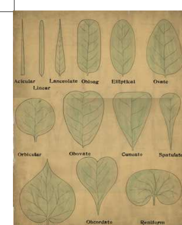
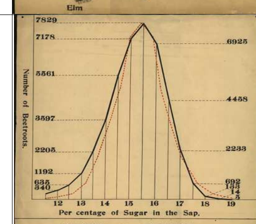
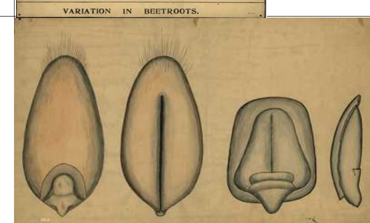
Buller's Watercolor Wall Charts

Panicle and Compound Umbrel	Churchward, Stanley G. (attributed to)			A04-025.004.0026.026.0001		
Untitled	Churchward, Stanley G. (attributed to)			A.04-025.006.0005.004.0001		
The Essential Constituents of Plant Food			Strasburger	A.04-025.004.0026.005.0001		
Smilax aspera	Buller, A.H.R. (attributed to)			A.04-025.004.0026.004.0001		
List of species (spermatophyta) Campanuales Order XLIV				A.04-025.003.0005.007.0001		
List of species Orders XXVII-XXXIII						
Variation in the size of the carapace of Portunus depurator in accordance with the law of Quetelet			De Vries			
Heliotropism in White Mustard seedling			Sachs			

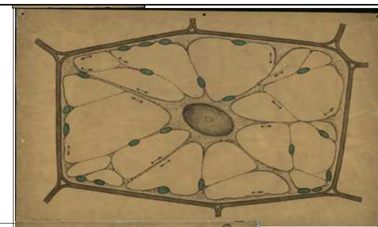
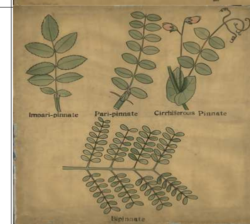
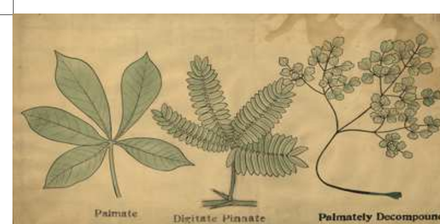
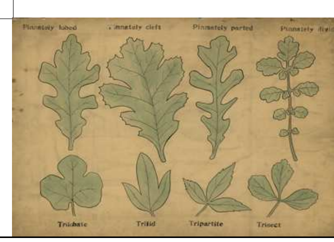
Buller's Watercolor Wall Charts

Diagrammatic section through inflorescent of Wheat						
Tentacle of Drosera responding to mechanical stimulus	Churchward, Stanley G. (attributed to)		Darwin	A.04-025.004.0026.002.0001		
Micro-Organisms from air collected on the roof of science school, South Kensington			Franklan, 1886			
The Mutation Theory: Genealogical Tree			De Vries - The Mutation Theory	A.04-025.005.0003.002.0001		
Section of Wheat Grain	Buller, A.H.R. (attributed to)			A.04-025.003.0009.001.0001		
Entire, serrate, dentate, crenate, sinuate, incised	Churchward, Stanley G. (attributed to)			A.04-025.003.0001.004.0001		
Accuminate, acute, obtuse, truncate, retuse, emarginate, obcordate, mucronate, cuspidate	Churchward, Stanley G. (attributed to)			A.04-025.003.0001.002.0001		
Two forms of leaf of Hornbeam	Buller, A.H.R. (attributed to)		De Vries	A.04-025.003.0001.003.0001		

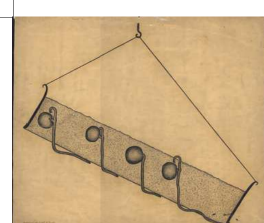
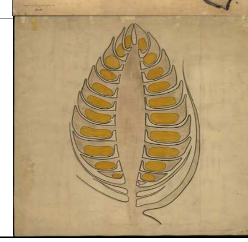
Buller's Watercolor Wall Charts

Selaginellales and Selaginella	I.E.S.			A.04-025.004.0026.022.0001		
Lycopodiaceae and Lycopodium clavatum	I.E.S.			A.04-025.004.0026.036.0001		
Eras						
Acicular, Linear, Lanceolate, Oblong, Elliptical, Ovate, Orbicular, Obovate, Cuncate, Spatulate, Cordate, Obcordate, Reniform	Churchward, Stanley G.			A.04-025.003.0003.001.0001		
Ash, Box Elder, Elm, Hop, Basswod Seeds	Churchward, Stanley G. (attributed to)			A.04-025.006.0015.001.0001		
Variation in Beetroots			De Vries	A.04-025.005.0003.004.0001		
Grain of wheat	Buller, A.H.R. (attributed to)			A.04-025.003.0009.002.0001		
Ripe antheridium of moss plant	Lowe, Charles (attributed to)			A.04-025.004.0026.015.0001		

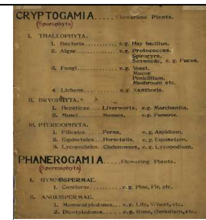
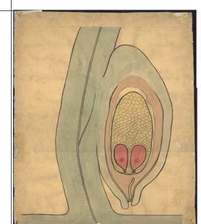
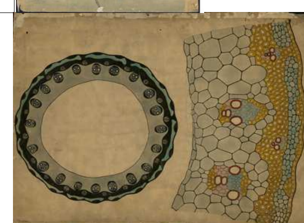
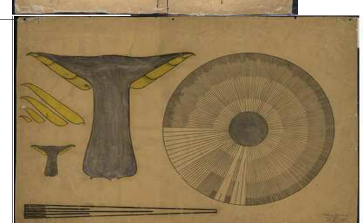
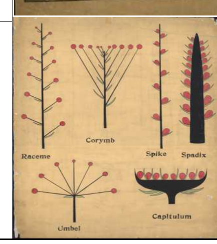
Buller's Watercolor Wall Charts

Typical Plant Cell			Barney	A.04-025.004.0026.016.0001		
Impari-pinnate, Pari-pinnate, Cirrhiferous Pinnate, Bipinnate	Churchward, Stanley G. (attributed to)			A.04-025.003.0002.001.0001		
Germination of Seeds of Pumpkin						
Marsilea on cotton						
Section through the ? of a grain of wheat						
Palmate, Digitate Pinnate, Palmately Decompound	Churchward, Stanley G. (attributed to)			A.04-025.003.0001.005.0001		
Sagittate, Auriculate, Hastate, Peltate	Churchward, Stanley G. (attributed to)			A.04-025.003.0001.006.0001		
Pinnately lobed, Pinnately cleft, Pinnately parted, Pinnately divided, Trilobate, Trilid, Tripartite, Trisect	Churchward, Stanley G. (attributed to)			A.04-025.003.0004.001.0001		

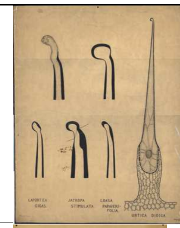
Buller's Watercolor Wall Charts

Drawings of two flowering plants						
Formation of Cambrian ring						
Seedling of Acacia pycnantha	Buller, A.H.R. (attributed to)		Strasburger	A.04-025.004.0017.001.0001		
U. S. ovary of wheat						
Vascular bundle ?? of Castor oil						
Cross-section of ?						
Hydrotropism of root of Pisum	Buller, A.H.R. (attributed to)		Sachs	A.04-025.004.0004.001.0001		
Untitled (Gynosperm cone with pollen)	Churchward, Stanley G. (attributed to)			A.04-025.006.0015.009.0001		

Buller's Watercolor Wall Charts

Cryptogamiaand Phanerogamia				A.04-025.003.0006.001.0001		
Hypogynous, Perigynous, Epigynous						
Cells						
Untitled (Gymnosperm ovual with germinating pollen)	Churchward, Stanley G. (attributed to)			A.04-025.004.0009.001.0001		
Stem of wheat	Churchward, Stanley G. (attributed to)			A.04-025.003.0009.004.0001		
Untitled (Pine branch with male and female cones)	Churchward, Stanley G. (attributed to)			A.04-025.004.0011.001.0001		
Tricholoma personatum gill system: single system is exact (x10) - cross section not quite exact in length of gill	Churchward, Stanley G. (attributed to)			A.04-025.006.0009.001.0001		
Raceme, Coryb, Spike, Spadix, Umbel, Capitulum	Churchward, Stanley G. (attributed to)			A.04-025.004.0015.001.0001		

Buller's Watercolor Wall Charts

Stinging Hairs	Churchward, Stanley G. (attributed to)		Haberlandt (p. 114)	A.04-025.004.0016.001.0001			
List of Species Pteridophyta & Spermatophyta, Orders I, II, III, IV	Buller, A.H.R.			A04-025.003.0005.002.0001