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Beyond Curie

Four women in physics and their remarkable discoveries

1903 to 1963

Scott Calvin

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Scott Calvin
Lehman College of the City University of New York

Morgan & Claypool Publishers

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For Erin Eisenbarth

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Acknowledgments

First and foremost, I want to acknowledge my fiancée Erin Eisenbarth, who came up with the idea for the book and has watched me wrestle with it all the way along. She is a historian, and I am a physicist, and I found her insights on how to do historical research invaluable. On occasion, I asked her to comment on sections or help me understand some thorny historical problem; at other times, she would encourage me not to allow myself to be too distracted with minutiae far removed from the main narrative. While I don't have the same kind of expertise to offer her as she completes her own dissertation, I hope I can at least help her in return by cooking us dinner, and perhaps baking the occasional batch of brownies, as she reaches crunch time in her own project.

I'd also like to acknowledge several former students of mine, each of whom is now a scholar in her own right: Jing Min Chia, who performed much of the investigation of Mayer's time at Sarah Lawrence, working with Abby Lester, the superb archivist at Sarah Lawrence College; Kristen Koopman, who invited me to Virginia Tech to give a seminar based on my preliminary work on the chapter on Cecilia Payne; and the historian of science Dr Kelly O'Donnell, who provided me valuable feedback on that same chapter.

One thing I have discovered about this process is that writing about history is hard. The historical record is full of apparent contradictions; modern writings often get taken in by legends that have grown up over time, or misinterpret key pieces of evidence. While I have uncovered a few instances where that has occurred, I am sure I have fallen prey to other misconceptions, and likely created a few new misinterpretations of my own. I look forward to hearing from readers who know better about one point or another, and themselves want to set the record straight.

Author biography

Scott Calvin

With a major in astronomy and physics and a minor in classics from the University of California Berkeley, followed by a PhD in chemical physics from the City University of New York, Dr Calvin has taught, conducted research, and advised students in a wide variety of institutions, including the Naval Research Laboratory, Brookhaven National Laboratory, the Hayden Planetarium, the Stanford Synchrotron Radiation Laboratory, Sarah Lawrence College, Examkrackers, and Lehman College. His course offerings have run the gamut, including innovative courses such as Crazy Ideas in Physics, Rocket Science, and Steampunk Physics, as have his books, including *We Can Do It! A Problem Solving Graphic Novel Guide for General Physics, XAFS for Everyone*, and the open-source artisanal pop-up book *National Synchrotron Light Source II: Long Island's State of the Art X-Ray Microscope*.

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Chapter 1

Introduction

1.1 Why am I writing this book?

People who know me are not generally surprised that I am writing this book; I have a wide range of interests, including the history of science and extending science education to underrepresented groups. But for some of those who just met me, there is a bit of surprise or even skepticism: a cursory scan of the author list for books about women in science shows that it's mostly (but not exclusively!) populated by women. Since I am not a woman, it could seem that there must be some special motivation that is driving me to write this book.

The truth, though, is there is no single reason or inspiring incident that led me to this topic. Instead, I can think of several inspirations that led me to write the book you now hold in your hands or see on your screen.

Ever since I read Ruth Lewin Sime's biography of **Lise Meitner**, Meitner has been a scientific hero of mine, a role model for experimentalists dedicated to the practice of science.

Soon after joining the faculty at Sarah Lawrence, I became aware that **Maria Mayer** had once taught there, and had gone on to win a Nobel Prize. At the time, I found that mildly interesting, but not compelling. But years before, as an undergraduate, I had greatly enjoyed the science fiction novel *Timescape*, written by the physicist Gregory Benford, and so I assigned it to my students in my freshman seminar. Upon re-reading it, I was delighted to find that a fictionalized Mayer appears in it as a character. Benford attended UCSD while Mayer was there, and had set a portion of the book during that time. Since many of the characters were fiction, I hadn't even been sure Mayer was a real person the first time I read the book, and I certainly hadn't remembered her name—but I did remember her key moment, and how it struck me. In *Timescape*, Gordon Bernstein, the main character, also a physicist, had come to a surprising conclusion about an experiment he was conducting, with the result that he was getting a lot of pushback from other physicists. The fictional Mayer asks Bernstein a question: 'Do you believe your

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results?' When Bernstein replied that he did, Mayer replies with a single word: 'Good.' That small affirmation is a lifeline for Bernstein, and I found it very moving.

One of the students in my freshman seminar, Jing Min Chia, also took an interest in Mayer. At first, she was researching women scientists in general, but Mayer, with her Sarah Lawrence connection, was a good place to start. Working with Abby Lester, Sarah Lawrence's masterful archivist, she soon found that many of the capsule biographies of Mayer were misleading, implying that Sarah Lawrence had considered her a 'nuisance'. Chia decided to refocus her investigation entirely on Mayer, and ended up writing an eight thousand word biography covering Mayer's time at Sarah Lawrence to set the record straight.

Chia's work was remarkable, particularly for a freshman, and now has the distinction of having been cited in the book Mayer's son Peter wrote about her life, on the website of the Sarah Lawrence archives, and in this book. In 2012, Sarah Lawrence held an early commemoration of the 50th anniversary of Mayer's Nobel, with a panel discussion which included, among others, Peter Mayer and Chia. Ironically, Mayer, who lived in Guam, happened to be in the United States at the time and attended in person, while Chia, who was a student at Sarah Lawrence, Skyped in from Malaysia.

Despite the attention it has received, Chia's work has never been published in full, a status I hope she will correct some day.

While I had read the autobiography of **Cecilia Payne** some years before, her story did not really strike me until I began to teach a year-long astronomy seminar at Sarah Lawrence. It was then that I became entranced by the Harvard Computers, the women who were responsible for so much of the progress of astronomy in the late 19th and early 20th centuries. I could see how Payne represented the next step of progress for women in the field, and how the torch was handed from one generation to the next.

And so when Jeanine Burke of IOP reached out to me to see if I had any ideas for a book in the Concise Physics series, I shared the query with my fiancée, Erin Eisenbarth, a feminist historian, who instantly thought of my interest in these women, and thought I should write a book about them.

And so I wrote a book about them.

1.2 An essential tension

All of the physicists in this book are scientists. In most contexts, I would no more refer to Meitner as a 'woman scientist' than I would to Newton as a 'man scientist.' (For that matter, despite the great anti-semitism Einstein faced, I do not usually use the term 'Jewish scientist' to describe him.) To do so, it seems to me, risks implying that there is such a thing as 'women's science,' a description the four scientists in this book would certainly dispute; Chien-Shiung Wu, for example, did so explicitly and repeatedly.

Lise Meitner is not a hero of mine *because* she is a woman, nor did I admire the Maria Mayer I first met in fiction for that reason. But how society and the scientific

community treated them was certainly influenced by their gender, and their responses to the challenges they faced add to my admiration for them.

But now I've placed them together in a book, so that they are tied together both by profession and gender. If I don't want to write about 'women physicists,' how am I to write about these four physicists who were women?

I decided, in each case, to focus on the event in each one's scientific career that she is best known for. Sometimes that happened at the start of a long, successful career, as was the case with Payne; sometimes near the end of one, as happened with Meitner. Using an event as a focus provides structure: how did each of these scientists get to that point? What obstacles did she face, what decisions did she need to make? Who were here allies, her rivals, and her detractors? How was the work recognized at the time? These questions could be asked of any scientist making a major discovery. Some aspects of the answers have little to do with the gender of the scientists in question, while others are due entirely to the fact that each was a woman.

Because of this structure, I didn't feel compelled to discuss, for example, the love life of each, or their deaths, or their physical appearance. But when one of those aspects was germane to the point at hand, I discussed it as a part of the context.

Some issues calling for extended discussion were likely to arise repeatedly: the process for awarding Nobel Prizes, for instance, or the question of child-care. In these cases I provided the primary discussion within one of the four chapters only. This has the side-effect that the chapters don't stand as well separately as they do together.

I also wanted this book to be helpful for people coming from a wide variety of backgrounds: among them scientists who want to know some history and historians who want to know some science. In order to serve those various audiences, and to provide some differentiation between this book and others that touch on the same historical figures, I've provided a science summary at the end of each chapter. For those who aren't interested in the science itself, these can be safely skipped. On the other hand, for those who want to understand the science before trying to unpack the history, they could be read first.

1.3 A few words on names

Three of the four physicists featured in this book at least experimented with taking their husbands' names upon marriage, raising the question as to how to refer to them in this book.

My guiding principle was to use the name under which they published the key work or works discussed in this book. This leads to modestly unconventional choices in two cases.

I write 'Cecilia Payne' (usually shortened to 'Payne'), because that was the name she used for her famous dissertation. Most modern authors, however, choose to use Cecilia Payne-Gaposchkin, the name she used after her marriage, both personally and professionally.

Maria Mayer is the trickiest case. Born Maria Gertrud Käte Göppert, she shared a first and last name with her mother, although her middle names were different. After marriage, she published some papers as Maria Göppert-Mayer, with the modestly Americanized spelling Maria Goeppert-Mayer also appearing. As her career progressed, though, she dispensed with the hyphen, leaving her full name as Maria Goeppert Mayer, sometimes written Maria G Mayer or simply Maria Mayer. Many modern accounts use Maria Goeppert-Mayer, including portions of the official Nobel Prize website. While not entirely wrong, as she did use that name a few times early in her career, it is not the way she referred to herself or published either at the time she did the work which won her the prize or at the time she was awarded it.

In addition, Maria's husband Joe Mayer plays a more important role in her scientific career then did the husbands of Payne or Wu. This would make referring to her as 'Mayer' throughout the text potentially confusing; perhaps this is why there is a preference for Goeppert-Mayer in many modern writings. My solution, admittedly imperfect, is to refer to Joe and Maria by their first names through most of their chapter, and to use 'Mayer' to refer to Maria Mayer in other chapters and in the science summary, where there is no danger of confusion with Joe. I have made this choice to honor her eventual preference for her own last name ('Mayer'), while still maintaining clarity in the text, and not treating her differently because of her gender (when she is 'Maria,' her husband is 'Joe').

The remaining cases are straightforward. Chien-Shiung Wu used Wu in her professional life, and Mrs Yuan (her married name) socially, being careful to maintain a rigid distinction between the two. Accordingly, she is 'Wu' in this book.

Lise Meitner maintained the same name throughout her life.

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Chapter 2

Cecilia Payne

2.1 Beyond Curie

In 1903, or thereabouts, a little English girl was being taken for an evening stroll in her baby carriage. A shooting star flashed across the sky; her mother told her it was a meteorite. It was the little girl's first taste of astronomy [1].

That girl, Cecilia Payne, had been born in the same year as the first Nobel Prize. Around the time she was shown the meteorite, the 1903 Nobel Prize in Physics was awarded to Henri Becquerel, Pierre Curie, and Marie Curie. Since the Nobel Prize itself was only three years old, it is a stretch to consider this a shattering of barriers. And in fact, it did not herald a new era of equality. When Marie Curie won her first Nobel, it meant that 5% of prize-winners, in all fields, had been female. As of this writing, in 2016, the fraction of female Nobel prize-winners has risen…to 5.4% [2].

Eight years later, in 1911, Marie Curie won again, this time being the sole recipient of the Nobel Prize for Chemistry. It was the first time anyone had won the Prize twice.

Cecilia Payne, the little English girl, was no longer quite so little. At school she had learned French, German, and Latin. She enjoyed solving quadratic equations and knew how to use a chemical balance.

It was not terribly unusual for a girl to develop those talents. Marie Curie, while certainly a topic of conversation, was not the only female scientist the young girl was likely to have heard of. The previous century had made celebrities of several: notably, the astronomers Maria Mitchell in the United States and Caroline Herschel in Germany, as well as the polymath Mary Somerville in Scotland.

Somerville, in particular, filled the role in the popular imagination that Curie would later occupy, particularly in the United Kingdom. An expert in mathematical astronomy and astrophysics, she also delved into geology, geophysics, ecology, chemistry, and biology. In 1834 she wrote a book *On the Connexion of the Physical Sciences* [3]. 'Astronomy', she wrote in its introduction, 'affords the most extensive

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example of the connection of the physical sciences. In it are combined the sciences of number and quantity, of rest and motion'.

In an early review [4] of Somerville's book, the philosopher of science William Whewell noted that Somerville's emphasis on the relation between the sciences was badly needed, as there was at that time no English word for 'students of the knowledge of the material world collectively'. Whewell refers to discussions in the British Association for the Advancement of Science, where labels were suggested and then rejected, including 'philosopher' (too broad), 'savans' (too French), and 'nature-poker' (too silly). 'Scientist' was also suggested, but at the time was not considered 'palatable'.

Whewell's work is the first time that the word 'scientist' is known to occur in print. It gradually gained currency, and would eventually be used to describe Somerville herself. While the term was not invented to describe her, nor was it invented by her, it was her work that gave an occasion for its introduction. It is reasonable, then, to describe Somerville as one of the inaugural class of scientists; the first group of scholars to be graced by that term during their lives.

On the Connexion of Sciences was a best-seller [5], and Somerville rapidly became famous. A sailing ship was named after her, with her likeness for a figurehead [6]. A famous sculptor was commissioned to create a bust of her to reside in the Royal Society [7] (figure 2.1)—an irony, since her sex debarred her from membership of that scientific organization—and the explorer Admiral Parry named an island after her. Shortly after her death, Oxford opened a college for women named Somerville Hall.

Mary Somerville was once a household name, but that is no longer the case, at least in the United States. Partially, that may be an effect of the passage of the time, and partially it may be that there is no single discovery or insight that encapsulates Somerville's career—no apple falling from the tree, discovery of radium, or realization of the double-helix structure of DNA. Another likely factor, however, was the rise of Marie Curie, who did not desire fame ('In science we must be interested in things, not in persons' [8]), but found herself drowning in it nonetheless. In 1912, following her second Nobel, the American papers anointed Curie 'without doubt the greatest of all women scientists' [9].

This praise of Curie marks a milestone of sorts. Somerville's scientific accomplishments placed her, in the words of one speaker, 'in the foremost ranks of modern physicists and speakers' [10]. While there was frequently discussion, and all manner of opinions, on the relationship between her gender and her scientific ability, it would have seemed strange to create a category ('women scientists') in which to rank her (figure 2.2).

By Curie's time, however, the profession of scientist was well-established, and there were just enough women in it to allow comparison within the group. Then, once a member of the public was told who is the greatest in what is implicitly a lesser category, why bother with the rest? The words used to praise Curie inadvertently swept aside other scientists who shared her gender.

This can be seen in figure 2.3, which shows the relative frequency of appearance of Marie Curie, Mary Somerville, and Caroline Herschel in American writings over

Figure 2.1. Bust of Mary Somerville at the Royal Society. © The Royal Society.

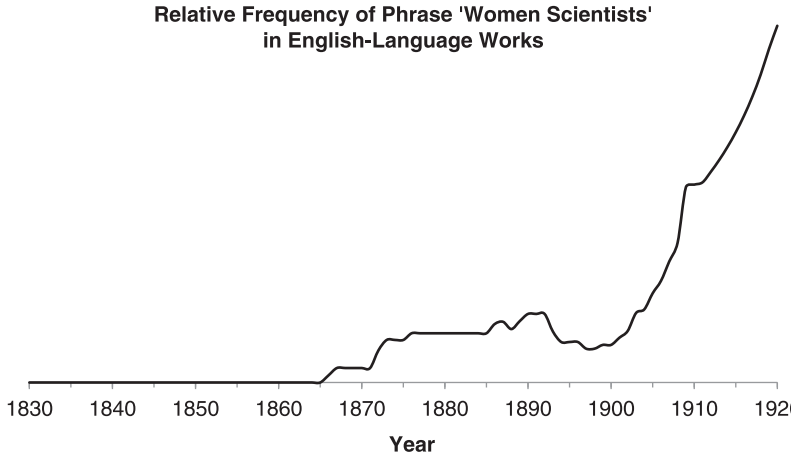

Figure 2.2. Google ngram frequency for phrase 'women scientists,' using smoothing of ten. 'Female scientists,' 'lady scientists,' and 'woman scientists' all had a negligible frequency during this period.

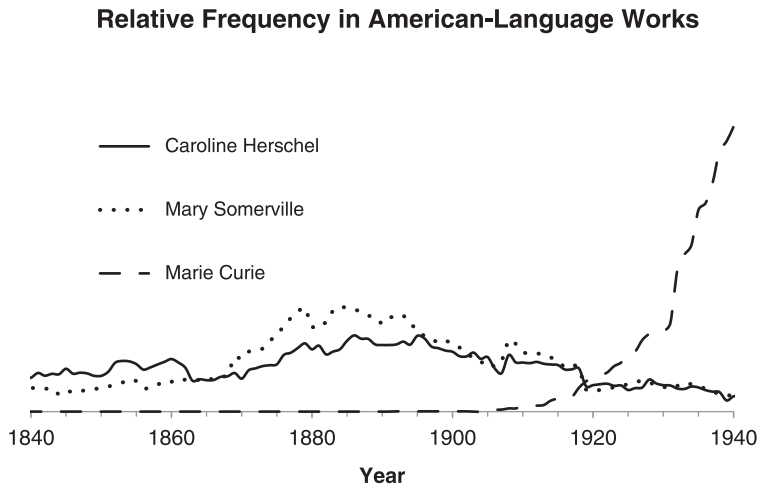

Figure 2.3. Google ngram frequency for each scientist's name, using smoothing of five. Note the sharp drop for Somerville and Herschel around 1920, when Curie was becoming a superstar.

time. Curie's gains in the early 20th century correspond to a sharp drop in references to the earlier scientists[1].

Payne, 11 at the time of Curie's second prize, would have known that science was not an impossible dream. She had already taken a private vow (to a spruce tree and an orchid!), years before, to dedicate herself to the study of nature. She set about making that dream not just a reality, but a passion, sneaking in to the small science lab at school:

> The chemicals were ranged in bottles round the walls. I used to steal up there by myself (indeed I still do it in dreams) and sit conducting a little worship service of my own, adoring the chemical elements. Here were the warp and woof of the world, a world that was later to expand into a Universe. As yet I had caught but few glimpses of it—the meteorite, Halley's Comet, the Daylight Comet of 1910. I had yet to realize that the heavenly bodies were within my reach. But the chemical elements were the stuff of the world. Nature was as great and impressive to me as it had seemed when I stood under the spruce tree and vowed myself to its service [1].

A few more years would pass, and Payne would become a young woman, freshly accepted in to Newnham College at Cambridge. She was ready to follow her dream.

[1] Maria Mitchell, an American, does not suffer the same fate in American writings. Likewise, the Scottish Mary Somerville persists into the Curie era much more strongly in British works. There is apparently space for national heroes alongside Curie.

2.2 No insuperable objections

When Payne entered Cambridge as a student of its all-female Newnham College in the fall of 1919, it was a time both of great optimism and, particularly for women, of great frustration. In her autobiography, Payne chose to emphasize the former, while not entirely neglecting the latter:

> The atmosphere was euphoric. The 'war to end war' was over…we women, of course had no votes (even had we been old enough), but that did not prevent us from conducting spirited debates. A new world was opening before mankind [1].

Ernest Rutherford had recently been brought back to Cambridge to direct the Cavendish Laboratory, and Cambridge Observatory Director Arthur Eddington, recently returned from his eclipse expedition testing Einstein's general theory of relativity, was on the verge of becoming a superstar in the popular press [11].

While women had been attending Cambridge for nearly half a century, they were not yet permitted to earn degrees or participate in its governance, despite repeated attempts to remove these prohibitions. The issue once again came to a head during Payne's time there, with a vote on both questions taking place in 1921. The votes established a compromise position: women could earn 'titular' bachelor's degrees, but without the governance rights awarded to men. A contemporary editorial [12], while purportedly on the side of granting governance rights to a limited number of women, was also sympathetic to the arguments of the opponents: to wit, that granting those rights meant 'Cambridge would be destroyed as a first-rate University for men', and that what women wanted was 'not to be fairly treated, but to get power in the University'. The editorial went on to provide sympathy to those who advanced those arguments, saying that male students found it 'just now almost as easy to hate the woman whom he imagines to be an unscrupulous rival as, in another mood, he might find, [sic] it easy to flirt with her'. Many of these male students, buoyed by their victory in the Cambridge Senate, celebrated by rioting in front of Newnham, badly damaging its historical gates, which were a memorial to Newnhan's first principal, the suffragist Anne Jemima Clough (figure 2.4). Payne, living behind those damaged gates and passing through them on her way to lectures in other parts of Cambridge, would have faced a daily reminder of the vitriol of those who would deny her the rights they held. Not that she would need the gates to remind her. As the editorial also states, the sentiment at Cambridge for keeping women out, or at least for keeping them in a second-class status, 'was largely guided by the medical and scientific men, who resent the way in which their places are usurped by women in laboratories'. Women, that is, like Cecilia Payne.

Students of natural science at Cambridge had to choose three subjects for their initial focus; Payne chose the unusual combination of botany, physics, and chemistry. At first, she believed she would specialize in botany when the time came to choose, but her interest and confidence in that subject were waning. Fortuitously, near the end of her first term she scored a ticket to Eddington's lecture on relativity and the results of his eclipse expedition. Payne was entranced; by her

Figure 2.4. Damaged gates at Newnham College. With permission from Newnham College, Cambridge.

recollection she was so shaken by the ideas that she did not sleep for three days. From that point forward, Payne committed herself to astronomy.

Not that she could simply do so. She had begun a course of study in the natural sciences. For historical reasons, astronomy at Cambridge was considered a branch of mathematics instead. So Payne chose to direct herself toward the study of physics, while attending as many lectures on astronomy as she could.

Before long, she reached the point where she was attending the advanced physics lectures given by the esteemed Rutherford. Regulations in place at the time required that women be segregated in the front row. Since she was the only woman attending, this made her very conspicuous. To make matters worse, Rutherford ritually humiliated her (regardless of what his intention may have been, that was the effect) at the start of each lecture, to the great amusement of the rest of the students.

That was physics, however, and what Payne most wanted was astronomy. One night when the Cambridge Observatory was having an event for the public, she came and so peppered the assistant manning the telescope with questions that he fled the scene. The assistant found Eddington and brought him back to help with Payne's questions, either by answering them or finding some other way to deal with her. By the time Eddington got there, Payne had taken over the demonstration, and was giving an extemporaneous lecture to the assembled visitors as she helped a young girl to look through the telescope. Taking in the scene, Eddington chuckled, and it was only then that Payne realized her idol had come in. It was now or never.

'I want to be an astronomer'.

Payne's recollection of the exact sequence of events that followed was a bit hazy, despite—or perhaps because of—the importance she later placed on them. That leaves us free to imagine the moment, somewhat as Payne later did: Eddington considered the young woman in front of him who had, for a few minutes, taken over

the duties of his assistant after asking him questions for which he had no answer, and was now giving her own answers to the public, using the Observatory's equipment. A brief pause, a raised eyebrow, and then Eddington's reply:

'I can see no *insuperable* objection'.

Eddington gave her the titles of books that would be helpful to read, only to find that Payne had read them all. Next, he gave her access to the Observatory library. Attendance at his lectures and his teas followed, and then research under his direction and her first publication, a four page paper on the proper motions of stars in and near the line of sight of the open cluster M36 [13].

But in those days, there was no way forward for a middle-class woman to become a professional astronomer in England[2]. The only career she saw open to her was that of schoolteacher. She needed a way out.

Her chance arrived in the person of Harlow Shapley, the new Director of the Harvard College Observatory (HCO), who came to London to deliver a lecture in 1922. Securing an introduction from a mutual acquaintance, Payne asked if she could come to work under him at the HCO.

Shapley's reply was flippant and facile—of course she could come…and then take over from Annie Jump Cannon, once Cannon retired. Cannon was then the leading member of the female astronomical staff known as the Harvard Computers, with her own title (Curator of Astronomical Photographs), numerous publications, and an international reputation, including an honorary doctorate recently awarded by the University of Groningen. Suggesting to Payne that she might be Cannon's eventual replacement would be like suggesting to a cub reporter for a newspaper that he might be the next editor—not impossible, but not likely, and it would involve jumping over a lot of other people.

Payne, however, heard the answer as 'yes', and proceeded to make it happen. She secured enough fellowships and grants to cover a year in the United States. Unlike many similarly-trained women of the time, she wasn't just looking for a job or for a way to satisfy a passion for astronomy. Cecilia Payne was looking to become a professional astronomer.

2.3 The Harvard Computers

Before we follow Payne's journey across the Atlantic, it is important to discuss the history of the community she would find when she arrived: the Harvard Computers.

As recently as 1971, the Oxford English Dictionary still defined a computer without any reference to the modern meaning of the word, solely as 'one who computes; a calculator, reckoner; *spec*. a person employed to make calculations in an observatory, in surveying, etc' [14]. The last sense given in the definition indicates

[2] That's not to say that there weren't female professional astronomers *in* England. For example, while Payne was still at Cambridge, A Vibert Douglas came from Canada to work with Eddington, in much the same way that Payne would go to America to work with Shapley. But Douglas soon returned to McGill University, in Montreal, to secure her doctorate [15], while Payne would remain in Massachusetts for the rest of her career.