THE WALK OF LIFE

VOL. 08

EDITED BY AMIR A. ALIABADI

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Biographical Essays in Science and Engineering

Volume 8

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2024

ISBN: 978-1-7751916-7-4

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I am in no degree ashamed of having changed my opinions.

—Bertrand Russell

Dedication

Ms. Golchin

Preface

The essays in this volume result from the Fall 2024 offering of the course *Control of Atmospheric Particulates* (ENGG*4810) in the Environmental Engineering Program, University of Guelph, Canada. In this volume, students have written about Ahmed Zewail, Bertrand Russell, Enrico Fermi, and Otto Hahn. Students have accessed valuable literature to write about these figures. I was pleased with their selections while compiling the essays, and I hope the readers will feel the same too.

Amir A. Aliabadi

Acknowledgements

I am indebted to my brother, Reza Aliabadi, a life-long mentor and inspirer for my ideas and directions in life, who also designed and executed the cover page for this volume. At last, I am thankful to each individual student author, without whom this project would not have been possible.

Amir A. Aliabadi

Contents

1 Ahmed Zewail (1946-2016)

Forging the Path to Modern Medicine at New Speeds

By Maham Nawaz, Amanda Peric, Isabella Wilches Mendoza, Noah Leong-Poi, and Anastasiya Kubrak

What drives a scientist to peer into the tiniest spaces and times, seeking answers that others cannot even imagine? Perhaps it is the pursuit of understanding: the need to answer questions that live just on the edge of possibility. Ahmed Zewail, a renowned Egyptian scientist and Nobel Prize winner, made groundbreaking work that revolutionized our understanding of molecular dynamics, while also demonstrating a deep empathy for humanity through his commitment to improving lives. Zewail's journey began with his early education in Egypt, where he developed a fascination for science, which led him to pursue higher education at the University of Pennsylvania and later at the University of California, Berkeley. His major contributions to science include the development of femtosecond spectroscopy, a technology capable of capturing chemical reactions on the femtosecond timescale. This advancement not only reshaped the field of chemistry but also had profound implications for engineering, enabling innovations in areas ranging from pharmaceuticals to environmental science, and his work has paved the way for future innovations in both academic research and real-life applications. Although the 1920s may have echoed with the roars of jazz and cultural revolution, Zewail's roar came decades later, shaking the very foundations of chemistry with his groundbreaking work, forever changing how we see the invisible world around us.

1.1 Childhood Days

It seems only fitting that Ahmed Zewail, whose work would bridge chemistry and engineering, was born in Alexandria, a city built on the pursuit of knowledge and was once home to the legendary Library of Alexandria, the beacon of learning in the ancient world. He remembers growing up in a world where the first word in the *Quran*, Iqra': "Read", encouraged a deep respect for knowledge, something that was universally valued. "People really valued knowledge," he says, emphasizing how the pursuit of education was seen as a way to achieve one's highest potential (Zewail and Aspaturian, 2017). For Zewail, this teaching was never about division between science and faith but rather about striving to excel, a notion encapsulated in the word jihad, which he grew up understanding as "to strive" or "to achieve your best." It was not the militant connotation that many associate with the term today, but rather a cultural call to pursue excellence, whether in science, education, or personal development. Zewail's childhood memories are filled with his thirst for knowledge and an early passion for science, especially mechanics. Despite his mother's limited education and his father's modest schooling, Zewail developed a love for learning that guided his career. He recalls organizing his own space as a child and writing "Doctor Ahmed" on his door at age 10 (Zewail and Aspaturian, 2017). Zewail grew up in an Egypt that was transitioning under President Gamal Abdel Nasser's regime, which he viewed with hope, especially for the promise of social justice and equality. He even wrote to Nasser at age 8, expressing his support for the new leadership and the country's future (Zewail and Aspaturian, 2017). Zewail describes the Egyptian bureaucracy with a mix of frustration and understanding. He acknowledges that although the system was slow and difficult, it was not malicious, just inefficient. He contrasts this with the deep respect for education in Egyptian society, where achievements in education were highly celebrated. Zewail's drive was not motivated by career or societal expectations but by a deep and intrinsic desire to understand the world scientifically. This idea of having a "calling," rather than pursuing science as a career for status, resonates with many who feel a similar passion for their fields of expertise.

1.2 Being in the Right Place at the Right Time

Zewail reflects on the importance of being in the right place at the right time. He believes he was fortunate to have received a high-quality education in Egypt during a transformative period after the 1952 revolution. Similarly, he recognizes that coming to the U.S. during the golden age of science in the 1960s was a rare and fortunate timing (Zewail and Aspaturian, 2017). He attended the University of Alexandria for his undergraduate degree in science as well as his master's degree in chemistry in spectroscopy, where he completed research while teaching students. Despite not having any connections outside of Egypt, and the American stock market being at a low point at the time, he did not let any financial obstacles derail him from his thirst for education and learning. He faced bureaucratic obstacles, including a delayed process to leave Egypt, but his determination to study in the West led him to apply independently to American institutions like Caltech and the University of Pennsylvania (Zewail, 2006). Zewail describes his initial experience in the US as a graduate student in the late 1960s, during a time of significant political and social upheaval, including the aftermath of the 1967 war between Israel and the Arab states. He was one of a small group of Egyptian students, and while he was keenly aware of the America's limited understanding of modern Egypt, he focused on his studies rather than becoming embroiled in political or nationalistic debates. After completing his Ph.D., he worked on his post-doctorate at the University of California, Berkeley. It was at this institution that the idea of picosecond (10^{-12} seconds) lasers first sparked life, which developed into a flame of discovery that he eventually carried on later in his work. Zewail did not just embody the desire to learn but to understand why things happened. Why do atoms behave the way they do? Why can't we see chemical reactions unfold in real-time? These questions would become the cornerstone of his work in the decades to come.

1.3 Femtosecond Lasers

For Zewail, the road to groundbreaking discovery was not just paved with knowledge but with persistence, patience, and a dogged refusal to accept the limitations of the era. It was this very determination that led him to challenge the very fabric of scientific understanding, refusing to be bound by the conventional tools of his time. Zewail's journey began in the 1970s and 1980s when he became interested in molecular dynamics and recognized the need for tools capable of capturing the intermediate phases of reaction, namely, fleeting stages within chemical reactions. These were the moments too quick for the eye to follow, but Zewail's relentless curiosity drove him to create the means to observe them. At the time, no technology existed to capture these transient states because they occurred on femtosecond timescales (10^{-15} seconds), an interval of time far beyond the capabilities of present imaging devices (Van Houten, 2002). As a result, Zewail developed femtosecond laser spectroscopy, which involved using ultra-fast laser pulses to "freeze" molecules in specific stages of their reactions, providing snapshots of molecular behaviour in real-time. By 1987, Zewail successfully demonstrated femtosecond resolution that captured intermediate reactions, which marked the birth of femtochemistry and landed him the recognition of being "the father of femtochemistry" (Van Houten, 2002).

A crucial application of Zewail's femtochemistry was his research on trans-azomethane, in collaboration with Eric W.-G. Diau. In this study, Zewail and Diau combined femtosecond spectroscopy with theoretical models to analyze the rapid molecular transitions of trans-azomethane during reactions (Diau and Zewail, 2003). This research allowed them to observe how chemical bonds broke and reformed within femtoseconds, precisely working out the intermediate steps in the reaction pathway (Diau and Zewail, 2003). This experiment demonstrated that femtosecond spectroscopy could capture even the most fleeting molecular changes, setting a precedent for studying biological molecules like proteins, enzymes, and DNA, which also undergo rapid changes pivotal to biological processes.

The discovery of femtosecond technology transformed drug development, surgical techniques, and diagnostic methods, offering new possibilities for improving patient care, treatment outcomes, and disease management. To begin, femtosecond (fs) laser technology provided a fast method for creating drug nanoparticles, essential for enhancing the efficiency of dose absorption. Laser fragmentation reduces the size of drug crystals while maintaining their shape, a key factor in preserving drug efficiency. By using fs laser technology, researchers can create these nanoscale particles with very small amounts of the drug, making it ideal for initial testing and screening. While effective for stable compounds, the technique may lead to degradation in more sensitive drugs due to high temperatures at the laser focal point (Kenth et al., 2011). However, even these challenges have not slowed the march of progress rather, they have fueled further innovation in the field. As the technology matures, implementing continuous flow systems could further mitigate degradation risks, making fs laser technology a promising tool for producing nanoparticles in cancer and infectious disease treatments. Femtosecond technology also holds great potential to revolutionize the diagnosis and treatment of diseases, offering new possibilities for early detection and targeted therapies. One application is femtosecond laser-induced breakdown spectroscopy (fs-LIBS), which could advance melanoma diagnosis during surgical procedures (Moon et al., 2018). Compared to traditional nanosecond lasers, femtosecond lasers reduce thermal effects, lower ablation thresholds, and finer spatial resolution (Moon et al., 2018). These advantages are particularly important in melanoma surgeries, where precise identification of cancerous tissue and safe margins is critical for both effective tumour removal and minimizing functional and cosmetic damage. Future femtosecond technology holds the potential to serve as an alternative that significantly reduces the risk of complications and enhances surgical outcomes.

Additionally, femtochemistry has opened the eyes of Ophthalmology with the introduction of femtosecond (fs) lasers. The ultrafast pulses that are produced from this laser can interact with the stromal tissue through electromagnetic radiation that can segregate the matter, forming free electrons (Callou et al., 2016). This technique was initially applied in eye surgeries, particularly in procedures involving the cornea, such as laser-assisted in situ keratomileusis (LASIK). Through further developments, this technique has aided in correcting myopia, presbyopia, and astigmatisms (Callou et al., 2016). This technology has also improved the treatment of presbyopia, a common age-related vision condition, by increasing precision and reducing spherical aberrations in the eye (Alió et al., 2015).

1.4 A Life in Perspective

It is plausible to say that Zewail's early life in Alexandria, shaped by a legacy of intellectual achievement, the challenges of post-colonial Egypt, and a personal commitment to education, likely played a role in fostering his compassion for humanity and his drive to use science as a tool for improving lives. Whether in advancing drug development to treat diseases more effectively, or refining surgical techniques that improved patient outcomes, Zewail's work was always underpinned by the desire to make a difference in people's lives. He saw science not as a field of abstract theory, but to alleviate suffering, enhance quality of life, and build a healthier, more sustainable future. Through his research, Zewail left a legacy that not only advanced scientific boundaries but also embodied a profound empathy for the human condition.

Ahmed Zewail did not just ride the wave of innovation, he made it crash into uncharted waters, leaving a trail of brilliance in his wake. His remarkable journey from his modest beginnings, to becoming a Nobel Prize-winning scientist is a testament to his brilliance and determination. His journey took him across the globe, from Alexandria to Philadelphia, from Philadelphia to Berkeley, and eventually to Caltech. Zewail's revolutionary invention of femtosecond spectroscopy, capable of capturing chemical reactions occurring in quadrillionths of a second, transformed our understanding of molecular dynamics, revealing unprecedented insights into chemical bonds and reaction pathways. His groundbreaking work transcended traditional scientific boundaries, influencing a wide range of disciplines, including biology, medicine, materials science, and nanotechnology. Real-time studies of molecular interactions paved the way for innovations such as targeted cancer therapies, precision drug design, and revolutionary eye surgeries using femtosecond lasers. These advancements reshaped diagnostics, minimized surgical risks, and uncovered critical new knowledge about DNA repair mechanisms (Van Houten, 2002). Zewail's legacy is defined not only by his scientific achievements but by his relentless pursuit of discovery, which continues to inspire researchers, engineers, and visionaries around the world, exemplifying the transformative power of curiosity and ingenuity. However, his work shows a commitment to humanity's progress, which remains his legacy.

2 Bertrand Arthur William Russell (1872-1970)

To Conquer Fear Is the Beginning of Wisdom

By Kimasha Arryasinghe, Tony Huynh, Trevor Tran, and Zachary Wesenger

2.1 Introduction

Bertrand Arthur William Russell, a leading thinker of the 20th century, was a philosopher, mathematician, and social activist whose work influenced many areas of human thought (Kreisel, 1973). Born in 1872 into British aristocracy, Russell's upbringing combined his grandmother's Victorian conservatism with his parents' progressive ideals. These influences shaped his curiosity and desire to challenge established norms, ultimately making him an important figure during the social changes of the early 20th century.

Russell's intellectual journey, influenced by his godfather John Stuart Mill, led him to question social norms, embrace agnosticism, and advocate for reason and evidence. During the 1920s, Russell supported social reform, women's rights, and peace, applying his philosophical principles to real-world issues.

Russell's contributions to philosophy were significant, especially in logic and mathematics. His collaboration with Alfred North Whitehead on *Principia Mathematica* sought to establish a logical foundation for mathematics, influencing analytic philosophy and modern logic (Russell, 1975). He believed in the power of reason and was willing to change his views with new evidence, saying, "I am in no degree ashamed of having changed my opinions" (Russell, 1961). This intellectual honesty shaped his philosophical and social efforts, helping make complex ideas accessible.

Beyond academia, Russell was an advocate for peace and social reform, opposing war, nuclear weapons, and social injustices (Doubleday et al., 2017). His activism, particularly during the World Wars and the Cold War, established him as a prominent public intellectual. Russell once said, "To conquer fear is the beginning of wisdom" reflecting his commitment to reason and compassion. His ability to connect philosophical ideas with pressing social issues made his contributions relevant even today.

This essay will explore three key aspects of Bertrand Russell's life and work: his early influences and intellectual development, his contributions to philosophy, and his advocacy for social reform and peace.

2.2 Russell's Early Influences and Intellectual Development

Russell's intellectual journey was largely shaped by his early influences, education, and experiences. Born into an aristocratic British family in 1872, Russell was influenced by the intellectual culture of his ancestors, many of whom were politically and socially progressive thinkers (Doubleday et al., 2017). The contrasting ideologies from his household mainly stem from his father, Viscount Amberley, who was an atheist and advocated for progressive ideas, while his grandmother, Lady Russell, who took over Russell's upbringing after his parents' death in 1872 and 1876, was deeply religious although encouraged intellectual curiosity. His godfather, philosopher John Stuart Mill, further inspired Russell's early fascination with reason and individual freedom, setting a foundation for his later emphasis on skepticism toward conventional beliefs (Doubleday et al., 2017).

Russell began his education in 1890 at Trinity College, Cambridge, after winning a scholarship to study mathematics, where he quickly distinguished himself, graduating as seventh Wrangler, a title for first-class honours, in 1893 (Griffin and Lewis, 1990). At Cambridge, he became close to influential figures like philosopher Alfred North Whitehead, whose mentorship guided Russell's understanding of logic as the key to addressing fundamental questions in mathematics and philosophy, and George Edward Moore, a fellow student. Immersed in both mathematics and philosophy, Russell earned a Fellowship in philosophy in 1895, solidifying his intellectual path (Griffin and Lewis, 1990). Russell was particularly influenced by the prevailing idealist philosophy taught at Cambridge, although he ultimately rejected it, preferring instead a rigorous, empirical approach focusing on observation, evidence, and logical reasoning.

Russell's early career was defined by his work in logic and mathematics. At first he wrote *An Essay on the Foundations of Geometry* in 1897 which discussed the Cayley-Klein metrics for the use in non-Euclidean geometry (Russell, 1897). In 1900, Russell attended the first International Congress of Philosophy in Paris, where he met Italian mathematicians Giuseppe Peano and Alessandro Padoa, who introduced him to the emerging science of set theory (Kennedy, 1973). Impressed by Peano's precision, Russell studied the materials they shared, including *Formulario Mathematico*, which led him to discover the famous "Russell's Paradox" (Kennedy, 1973). Russell's Paradox reveals a contradiction in naive set theory, arising when considering the set of all sets that do not contain themselves, as this set both must and must not contain itself, leading to a logical inconsistency. His next renowned work is his three-volume *Principia Mathematica*, published from 1910 to 1913 in collaboration with Whitehead. This work is on the foundations of mathematics and advanced the thesis that mathematical truths can be derived from logic, a set of axioms and rules of inference (Peano and Ratti, 2024). The result of his work propelled his status as world-famous in the field.

Following the success of his work, Russell became involved in political activities, running as an Independent Liberal candidate in the 1907 Wimbledon by-election, though he was not elected (Craig, 1974). In 1910, Russell became a lecturer at Trinity College, Cambridge, where he had previously studied. Although he was considered for a fellowship that would secure his position and allow him a vote in the college government, he was ultimately passed over due to his agnosticism. Around this time, he met the Austrian student Ludwig Wittgenstein, who became his Ph.D. student and who Russell saw as a promising successor in the field of logic. Despite Wittgenstein's frequent crises, Russell supported his development, eventually encouraging the publication of Wittgenstein's *Tractatus Logico-Philosophicus* in 1922.

2.3 Contributions to Philosophy: Logic, Mathematics, and Reason

Russel greatly contributed to the philosophical development of logic, mathematics, and reasoning. The earliest example of Russel's contributions to the field of logic was the discovery of "Russell's paradox" (Whitehead and Russell, 1910). This paradox highlighted a fundamental problem in naive set theory; when considering the set of all sets that do not contain themselves (Whitehead and Russell, 1910). This paradox ushered a major rethinking of the foundations of the theory and lead to later developments of axiomatic systems such as Zermelo-Fraenkel set theory. Although Russell had other significant contributions to the field of logic, one of Russell's most famous contributions was the 1914 logical atomism proposed in *Philosophy and Knowledge*. Russell proposed that the world consisted of atomic facts, or basic and indivisible truths. Russell believed that language should be logically analyzed as an atomic structure where complex propositions could be broken down into simpler components. Logical atomism was highly influential in shaping the course of analytic philosophy and influenced the Vienna Circle's development of logical positivism.

Many of Russell's contributions to the philosophy of logic also pertained to the philosophy of mathematics. In addition to Russell's paradox, Russel also co-authored the *Principia Mathematica* published between 1910-1913 along with Alfred North Whitehead. This work aimed to derive all of mathematics from logical axioms using symbolic logic (Whitehead and Russell, 1910). This philosophy was termed logicism and reshaped the philosophy of mathematics by challenging prior conceptions of mathematical independence from logic. Russell and Whitehead's contributions would lead to the development of philosophies such as formalism and constructivism. During the period between the publication of the *Principia Mathematica*, Russell would further contribute to the philosophy of mathematical knowledge. In *The Problems of Philosophy*, Russell argued against psychologism which viewed mathematics as a product of human minds and sought to show that mathematical knowledge was objective (Russell, 1912). As a result of Russell's argument, several subsequent philosophical debates on mathematics were sparked, influencing the works of other philosophers such as Kurt Gödel.

Much like Russell's contributions to math, most of Russell's contributions to the philosophy of reasoning was grounded in logic. In *The Problems of Philosophy*, Russell argued that logic was crucial in achieving certainty and that knowledge was grounded in the application of logical principles. Furthermore, in the same treatise Russell emphasised that logical reasoning was essential to human understanding (Russell, 1912). Russell argued that logical analysis could discern worldly truths even without empirical evidence so long as the reasoning was logically sound. Russell's arguments greatly influenced 20th-centurey epistemology influencing philosophers like Karl Popper and cemented the importance of logical reasoning for obtaining knowledge. Lastly, Russell was also a lifelong critic of metaphysics because he believed that the reasoning behind the claims could not be logically or empirically verified. This rejection of metaphysical claims and emphasis on logical reasoning would lay the groundwork for logical positivism influencing 20th-century science (Russell, 1945).

2.4 Advocacy for Social Reform and Peace

Russell published his many views on international conflicts. During World War I, Russell disagreed with England's role and protested violent resistance (Kreisel, 1973). He also hated the majority's enthusiasm for war and violence (Russell, 1975). In 1915, Russel wrote his political philosophies in his book *Principles of Social Reconstruction*. In it, he suggests that impulses, such as religion, education, and marriage should accelerate reform rather than State, poverty, and war (Russell, 1975). He was arrested in 1918 for potentially creating disloyal troops (Kreisel, 1973). Once the war ended, he focused on the possibility of world peace.

However, in World War II, his view on war changed. Russell believed that the Nazis and Adolf Hitler's Germany were horrifying and cruel, and that the war would be difficult (Russell, 1975). For England to win, he needed to support the war. After the atomic bombs in Japan, Russell spoke in the United Kingdom's Parliament on the importance of controlling nuclear bombs and the potential creation of more powerful bombs (Russell, 1975). While his audience agreed, they did not think it was relevant. By 1950, Russell received the Nobel Prize in Literature for *Marriage and Morals*, a book containing his progressive views on the roles of a husband and wife, which he later thought was his last sign of public approval (Russell, 1975). Russell then published a book on the Vietnam War's atrocities, which led to both disapproval and high sales (Russell, 1975). He and his colleagues believed that the war must end quickly. They established the Vietnam Solidary Campaign to protest the Vietnam War and to hold England accountable for its support (Russell, 1975).

During the Cold War, Russell insisted that atomic bombs were dangerous. Areas could become inhabitable, and all civilians could be at risk (Russell, 1961). Russell would write to both President Eisenhower of the United States and Premier Khrushchev of the Soviet Union. He believed that agreements between the countries could prevent the dangerous spread of nuclear weapons (Russell, 1961). In 1961, Russell was again arrested for a public speech opposing nuclear war (Russell, 1975). Russell and his colleagues eventually created the Atlantic Peace Foundation for educating war and peace, and the Bertrand Russell Peace Foundation for more political work (Russell, 1975). Through his essays, Russell firmly opposed communism. Yet, he believed it could not be stopped through war (Russell, 1961).

Russell wrote that the only way for world peace was with a global government controlling all major weapons, with a separate legislative and judicial body, and loyal armed forces (Russell, 1961). These forces would oppose any nation that uses force against another. However, his view on establishing a world government was more complex. He believed that some nations would willingly join this government, while others would be forced to, as he did not think all humans would freely cooperate (Russell, 1961). By the end of the century, his many publications on his political philosophies were well-documented.

2.5 Conclusions

In conclusion, Bertrand Russell's legacy shows how powerful clear thinking, a strong moral stance, and bravery can be. His work in philosophy, especially in logic and mathematics, changed how people think about these fields and set the stage for modern philosophical discussions. His major work, *Principia Math-*

ematica, proved that logical thinking could be used to build a solid foundation for all of mathematics. But Russell wasn't just an academic; he cared deeply about using his knowledge to make the world better. He stood up against World War I when he felt it was wrong, and later called for peace and the control of nuclear weapons during the . Even when his beliefs brought criticism and even imprisonment, he stayed true to what he believed was right. Russell's books, such as *The Problems of Philosophy* and *Principles of Social Reconstruction*, continue to inspire people today, reminding us that clear, logical thinking paired with strong ethics can lead to social change. His ideas about global cooperation, peace, and human rights still matter and push us to think about similar issues now. Bertrand Russell's life and work show that deep thinking and acting on one's beliefs can create change that reaches far beyond academic circles and impacts society in meaningful ways.

3 Enrico Fermi (1901-1954)

A Short but Flourishing Life

By Mason Philpott, Riley Wilson, Kyle Saunders, and Aditya Parameswaran

3.1 Close Friendship with His Brother

Enrico Fermi was born on September 29, 1901, the son of Alberto and Ida De Gattis Fermi. The relatively small family for the times lived a modest life in Rome, Italy, with his father working as a government railroad inspector and his mother a schoolteacher. He grew up the youngest behind his two siblings Maria (b. 1899) and Giulio born only a year later (Fermi, 1954). It has been said that Fermi did not have much of an educational background as his father was the first to break from a long line of farmers. The two brothers, however, took to a deep fascination with both mathematics and physics; at the age of 10 years old Fermi and his older brother had constructed many toys and even an electric motor (Bruzzaniti, 2016). This relationship with his older brother was quite significant to Fermi's developing years and could point to the reason he took interest in the sciences to begin with. It was common for Giulio to share his science books with a young Fermi (Bruzzaniti, 2016).

Unfortunately, tragedy struck in 1915 when his brother passed away at the age of only 15 due to complications during surgery on a throat abscess (Bruzzaniti, 2016). This would have a large impact on the family, especially Fermi, who would resign himself to books on mathematics and physics to take his mind off the loss of his brother. This may have been the pivotal event in Fermi's life which would lead him to a life of scientific accomplishment, possibly due to his brother's early authority.

3.2 From Italy to the United States

The influences present in his teenage years were critical in developing his engineering mindset and his natural ability toward understanding complex phenomena. In 1918 he gained admission to the University of Pisa, a prestigious academy in Italy; this was achieved due to a popular dissertation that he wrote entitled: *Distinctive Features of Sounds and its Causes* (Bruzzaniti, 2016). At just 21 years old, Fermi received his doctorate in physics from the University of Pisa. This was just one of the first steps in his career, setting the stage for all of his future achievements.

Wartime efforts in Italy, especially World War II (WWII) had a significant impact on Fermi's life, as well as his career altogether. In 1938 the Italian government showed no protest to the annexation of Austria by Germany, a foreshadowing of the support Italy would show towards Germany a few years later (Bruzzaniti, 2016). At this time, it is also important to address the lack of funding that Fermi and his research was receiving due to the Mussolini's reallocation towards the wartime efforts in Ethiopia and later World War II (Di Scala, 2005). At this time in his life, Fermi's focus was neutron physics and the discovery of new isotopes; he was desperately interested in acquiring the funds for a particle accelerator, which was becoming very popular (and useful) in America. Eventually he was allotted the funding indirectly from Mussolini's government via Consiglio Nazionale delle Ricerche (National Research Council, founded in 1923) (Di Scala, 2005). These funds were used for the construction of a more traditional model of a particle accelerator, a design which was not up to par with current American technologies that his former collogues were reporting (Di Scala, 2005).

Another signal of Fermi's soon departure from his homeland was his detestation of politics, especially the fascist beliefs of his time. On July 14, 1938, the Italian antisemitic campaign published the manifesto of race, declaring that Italians are of pure Aryan race and stated that Jews did not belong in this group. Fermi also detested the fascist governments' use of science as a basis to form their antisemitic beliefs and its use as propaganda to allow for the party's progression of political policies. Shortly after laws were constructed to repress foreign jews; It only took a month for these laws to extend to Italian Jews (Di Scala, 2005). This had serious implications for his wife Laura, a Jewish lady. At this point in his life, it became clear to Fermi and his family that they needed to leave their beloved country due to the approaching crisis.

By chance of luck, it was November of this same year that Fermi had won the Nobel Prize for his work on neutrons and the discovery of countless new isotopes; an achievement that was downplayed by the fascist regime due to his lack of political interest/support (Bruzzaniti, 2016). A trip to Stockholm to accept his award allowed Fermi to write a letter to Professor George Braxton Pegram of Columbia University, free from interception from the Italian government. Contained in this letter was the intentions to leave Italy and work at the university. He requested certain facts to be provided, such as the job offer and salary so he could present it to the Italian embassy and leave his country without the pretenses of being a political refugee (Bruzzaniti, 2016). On November 6, 1938, Fermi left his country to commence a new chapter in his life.

3.3 Contributions in America

Fermi became a citizen of the United States in 1944. Over the course of his career in science and engineering, Fermi was responsible for a number of major advancements in the world of physics. As noted in the previous paragraph, Fermi was awarded the Nobel Prize in Physics in 1938, for his identification of new radioactive elements, made in connection with his work of nuclear reactions. This work was a precursor to the Manhattan Project, which was an effort to develop the first atomic bomb during World War II. The project was led by Robert Oppenheimer, and Fermi played a very important part in the process (Goldwhite, 1986). Prior to a nuclear bomb being created, Fermi and his team developed the first nuclear reactor. Fermi successfully created the world's first self-sustaining controlled nuclear chain reaction (Steeves, 2021). This was a huge step in harnessing nuclear energy, and it paved the way for nuclear science as a whole. Outside of the world of nuclear energy, Fermi also made substantial contributions to the development of quantum theory, especially in understanding the electron behavior in atoms.

As stated, Fermi's contributions to the Manhattan Project began with designing the first nuclear reactor to become self sustaining. This reactor was the Chicago Pile, an early liquid fuel nuclear reactor being tested at the Metallurgical Laboratory at the University of Chicago. This process, guided by Fermi, became the first reactor to generate a self-sustaining nuclear reaction, where the neutrons generated by nuclear fission are sufficient to create new fission reactions. The success of this experiment earned him the moniker of "The Italian Navigator."

The Chicago Pile-1 reactor was a simple, by today's standards, nuclear reactor. It was the first artificial nuclear reactor, constructed under the leadership of Enrico Fermi in 1942. Unlike modern reactors, it used natural uranium as fuel and graphite as a moderator to slow down neutrons. The reactor operated on the principle of achieving a self-sustaining nuclear chain reaction. Neutrons released by fission events were slowed by the graphite to increase the likelihood of inducing further fission in uranium-235. The reaction intensity was controlled using cadmium-coated control rods, which absorbed excess neutrons when inserted into the reactor. This ensured that the reaction remained stable and did not become runaway.

After the success of Chicago Pile-1, Enrico Fermi and his team focused on the development of follow-up reactors, CP-2 and CP-3, built at the Argonne site near Chicago. CP-2 was a reconstructed and upgraded version of CP-1, utilizing the same natural uranium and graphite design but operating at higher energies and with better shielding and monitoring. CP-3, on the other hand, was the first reactor to demonstrate the use of heavy water as a moderator, showcasing its effectiveness in nuclear power generation. Both reactors implemented improved safety measures, including an automatic control rod system designed to rapidly halt the chain reaction if necessary. CP-3 also featured a drainable heavy water tank, an additional safety mechanism to shut down the reactor by removing the moderator.

The information from these reactors was crucial in determining the critical mass conditions required for the Manhattan Project, as critical mass values had previously been only theoretical. The data and design principles also informed the creation of the B Reactor at Hanford, the world's first large-scale nuclear reactor, which produced the plutonium used in the Manhattan Project. Enrico Fermi personally inserted the first uranium fuel slug into the B Reactor and played a key role in its operation and maintenance. Notably, Fermi identified the cause of the reactor's mysterious shutdowns, diagnosing it as xenon poisoning, a phenomenon where the fission product xenon-135 absorbs neutrons, temporarily halting the chain reaction.

At the Los Alamos research facility, Enrico Fermi was assigned to the F-Division, where he contributed to critical areas of research, including neutron transport and reactor design. He was present at the Trinity test, which demonstrated the implosion mechanism used in 'Fat Man,' the bomb later dropped on Nagasaki. During the test, Fermi famously offered a dark-humored remark speculating on whether the explosion might ignite the atmosphere, though the risk had been ruled out beforehand. This comment became legendary, though there is no verified account of formal wagers made by Oppenheimer or Kistiakowsky regarding the bomb's success.

After World War II, Enrico Fermi joined the Institute for Nuclear Studies at the University of Chicago, where he continued his groundbreaking contributions to experimental and theoretical physics. His post-war research centered on high-energy physics and the interactions of subatomic particles, particularly pion-nucleon interactions. This work proved pivotal in advancing the understanding of fundamental forces at the subatomic level. Fermi's ability to seamlessly integrate complex theoretical frameworks with experimental investigations solidified his legacy as a foundational figure in modern particle physics. (Segrè and Hoerlin, 2016).

Fermi's role as a teacher was as influential as his scientific work, and he became known for his clear explanations and engaging style. His students fondly nicknamed him 'The Pope' due to his immense knowledge and respected status in the scientific community. Many of his students including Nobel laureates such as Chen Ning Yang and Owen Chamberlain, went on to make groundbreaking discoveries, often crediting Fermi's mentorship and influence. His informal, hands-on teaching style fostered an enduring culture of scientific curiosity and rigor, shaping generations of physicists and solidifying his legacy as a mentor (Segre, 1970).

3.4 Perspective

Fermi's impact on physics and engineering is memorialized through numerous honors and namesakes. The discovery of the element fermium (Fm) and the naming of Fermilab, a major particle physics research center in Illinois, recognize his foundational contributions to nuclear physics and particle science. His innovations in nuclear theory, statistical mechanics, and experimental techniques continue to influence research across multiple scientific fields, underscoring Fermi's lasting legacy as one of the 20th century's most significant physicists (Segrè and Hoerlin, 2016).

4 Otto Hahn (1879-1968)

The Father of Nuclear Chemistry

By John David Pomeroy, Dima Abdul-Ghani, Goral Prajapati, and Maya Ali

4.1 Introduction

Otto Hahn's contributions to nuclear chemistry marked a pivotal moment in scientific history, one that reshaped both scientific understanding and global power dynamics. In 1938, working alongside Fritz Strassmann, Hahn uncovered the process of nuclear fission, a discovery that enabled the release of vast amounts of atomic energy and laid the groundwork for nuclear power and atomic weaponry (Hahn, 1958; Maddox, 1970). While this achievement solidified Hahn's status as a leading scientist of the 20th century, his legacy is deeply intertwined with the ethical and political complexities of his time. Conducting groundbreaking research within Nazi Germany, Hahn found himself at the center of a scientific landscape heavily influenced by wartime imperatives and political pressures (Sime, 2012). His involvement in Germany's nuclear program during World War II has been the subject of extensive analysis and debate, with questions surrounding his intentions and ethical stance amidst the conflict (Sime, 2012). This essay examines the life and legacy of Otto Hahn, covering his formative years, major scientific breakthroughs, and the challenging moral terrain he navigated. Through a detailed exploration of Hahn's contributions and the historical context in which he worked, this essay seeks to provide a nuanced understanding of the enduring impact and ethical considerations associated with his discoveries.

4.2 Early Life and Education

Otto Hahn was born on March 8, 1879, in Frankfurt, Germany, into a family that valued both business and intellectual pursuit. His father, Heinrich Hahn, a successful businessman, saw the potential in young Otto's scientific curiosity and encouraged his academic ambitions, setting a foundation for what would become a distinguished career in chemistry (Kragh, 2009). By the age of eighteen, Hahn had already developed a fascination with chemistry, particularly with understanding the natural world at its most elemental level. This early passion for scientific inquiry led him to the University of Marburg in 1897, where he immersed himself in the study of chemistry and mineralogy. Hahn's academic journey was rigorous and filled with curiosity-driven exploration, which further deepened during his studies under the Nobel Prize-winning chemist Adolf von Baeyer at the University of Munich. Von Baeyer's guidance introduced Hahn to the emerging field of radiochemistry, an area that would become central to his scientific identity. The influence of such a prestigious mentor fueled Hahn's ambitions and provided him with a solid grounding in the innovative methods of the time (Sime, 1997).

Hahn's education took an international turn when he traveled to London to conduct research at University College London. Under the mentorship of Sir William Ramsay, renowned for his discovery of noble gases, Hahn refined his skills in experimental techniques and expanded his interest in radioactivity (Kragh, 2009). During this period, Hahn successfully isolated a new substance, which he named radioactinium, marking his first significant contribution to radiochemistry. This early success solidified Hahn's commitment to scientific research and connected him to a network of pioneering researchers who were also captivated by the mysteries of atomic science. His experiences in London and later in Berlin allowed him to explore chemistry beyond conventional studies, equipping him with the advanced skills and knowledge that would underpin his groundbreaking work in nuclear science (Kragh, 2009).

4.3 Major Scientific Contributions and Struggles

Hahn's discovery of nuclear fission stands as a cornerstone in modern science, yet his contributions extend beyond pure scientific achievement. In 1938, working with Fritz Strassmann, Hahn identified barium as a product of uranium atom splitting, thus uncovering the process of nuclear fission (Hahn, 1958; Maddox, 1970). This discovery was transformative, unveiling the potential to release vast amounts of energy from atomic nuclei, a breakthrough later explained theoretically by Lise Meitner and Otto Frisch. Hahn's work set the stage for nuclear power and weaponry, marking a profound shift in scientific and geopolitical landscapes (Hahn, 1958; Sime, 2012).

However, Hahn's legacy is intertwined with the ethical challenges posed by his work during World War II. As director of the Kaiser Wilhelm Institute (KWI) for Chemistry, Hahn played a central role in Germany's nuclear fission project, conducting research that held potential military applications. Although he maintained post-war that his research was purely scientific, historical analyses suggest otherwise (Sime, 2012). They reveal that Hahn's institute was involved in several military-related projects, including studies in neutron physics, isotope separation, and transuranium elements, research that was classified and closely tied to the war effort. Despite Hahn's later claims of "pure science," his involvement with the Nazi regime's scientific programs illustrates the complex moral landscape he navigated .

Hahn himself expressed regret over the application of his discovery in atomic bombings, a sentiment recorded in his reflections after the war. This internal conflict highlights the ethical weight of his scientific contributions. While he achieved significant advancements, the implications of his work haunted him, underscoring his struggle to reconcile his scientific ambitions with the destructive uses of nuclear fission (Hahn, 1958; Maddox, 1970).

4.4 Sociopolitical Context, the Atomic Bomb, and Ethical Reflections

Otto Hahn's career and scientific developments occurred during a tumultuous period in global history. Specifically, Hahn worked through the rise of the Nazi regime, World War II, Post World War II events, as well as the beginning of the Cold War. It is key to explore the sociopolitical climate present during his career to better understand the context behind his work and his intentions as a scientist. As a German scientist within the Nazi regime, Hahn was placed at the intersection of political affairs, ethical dilemmas, and his personal scientific achievements. There is still debate as to whether Otto Hahn was truly focused solely on his science, or if he had underlying political biases. Those that argue the latter often reference his passiveness and inaction during the varying sociopolitical climate of his career (Sime, 2006).

Otto Hahns was a prominent German scientist during the rise of the Nazi Regime. While he did not admit he was a Nazi or shared Nazi beliefs, he initially spoke kindly of Adolf Hitler. Specifically, in 1933 during an interview with the Toronto Star, Hahn defended Hitler, stating that he was a hope for German youth, a hero, and compared his qualities to that of a saint. He also denied that the anti-Semitic actions of the regime were attributed to Hitler (Sime, 2006). Of course, as the years prior to the war went on, the brutalities of Hitler's regime became more evident and difficult to defend. The regime wished to control all parts of German society including science. As the director of the KWI, Hahn was involved in the dismissal of his Jewish, "politically undesirable" colleagues. During this time, Hahn maintained a more passive stance. Hahn was caught at the intersection of his scientific ambitions, personal relationships with the colleagues, as well as the pressures of the Nazi regime (Sime, 2006). While he expressed uneasiness with these policies privately, he remained passive and complicit in public.

In 1938, Hahn made significant contributions to the field of nuclear physics through his discovery of atomic fission. This groundbreaking discovery paved the way for the German Atomic Project, which was founded in 1939 after the outbreak of the war. This project aimed to investigate the potential military applications of Hahn's discovery. Within the project, Hahn's expertise lied in radiochemistry, specifically in studying the behaviour of radioactive elements rather than the physics behind creating a nuclear weapon. It is a point of debate whether Otto Hahn actively participated in and pursued the development of a nuclear bomb for Nazi use during the war, or if he was truly unaware of the military potential of his discoveries and his work within the project. Either way, it is evident that Hahn's position during the war was complex. On one hand, he was one of the most prominent German scientists of the time and was influenced by his personal ambitions to remain passive in order to continue pursuing his research with the German Atomic Program. On the other hand, he was challenged with the growing pressures from the regime, and it is possible that he remained passive due to fear. Either way, while other scientists such as Neil Bohr spoke out more actively, Hahn was notably silent.

After the devastating use of the atomic bomb in World War II, Hahn was deeply regretful and dismayed at the consequences his discovery had led to. He became a vocal advocate for the responsible use of nuclear energy. In 1948, he became the president of the Max Planck Society, devoting himself to the opposition of nuclear weapons. Furthermore, he was a key player in the denazification of the scientific community in Germany (Sime, 2006). During the period of the Cold War and the ensuing arms race, Hahn was an active voice of opposition as more destructive advancements were made. In 1955, he broadcast a radio speech appealing to powers on both sides of the Iron Curtain titled *Cobalt 60 - danger or blessing for mankind?* He warned of the dangers of nuclear weapons and the responsibility held by political leaders to not bring both the world and their countries to their ends. Additionally, he helped draft the Mainau Declaration of 1955, once again warning of the dangers of the sciences he helped create.

Despite this, many point out that while he spoke out against the use of nuclear weapons, he was selectively silent about his own wartime work. While we cannot confirm his feelings towards the German Atomic Program and the Nazi Regime, Hahn played a significant role in the rehabilitation of the scientific community and maintained a consistent anti-nuclear weapon stance post World War II.

4.5 Legacy and Impact on Future Science

Otto Hahn's work was essential to revolutionizing modern science. Known as the "father of nuclear chemistry," he left a lasting impact of the field of nuclear science. He discovered several radioactive isotopes used for research purposes and radioactive recoil, although his most important contribution is his discovery of nuclear fission in 1938. This discovery laid the foundation for nuclear weapons and nuclear energy, fields which are still making advancements around the world today. The use of nuclear energy to generate power was explored after World War II using Hahn and his colleagues' research as a foundation. Lise Meitner, a colleague of Hahn, would continue to research nuclear reactions, eventually going on to help create Sweden's first nuclear reactor in 1954. She would also later write in 1963 reflecting on Hahn's contributions to science: "The discovery of nuclear fission by Otto Hahn and Fritz Strassmann opened up a new era in human history". It is evident that Hahn played a critical role in the development of modern science. However, it is also worth stating that the moral dilemmas faced by Hahn during his career highlight the importance of ethics in the pursuit of knowledge. Ultimately, his life teaches modern scientists that it is crucial to be aware of the broader implications of scientific advancements, especially during complex sociopolitical landscapes.

4.6 Conclusion

In reflecting on the life and contributions of Otto Hahn, it becomes clear that he was a figure of profound impact within both the scientific community and broader society. His work in radiochemistry, culminating in the discovery of nuclear fission, not only marked a turning point in scientific understanding, but also ushered in an era that reshaped global energy and warfare. Hahn's scientific rigor and dedication to discovery were matched by the complex ethical terrain he navigated, particularly during the tumultuous years of World War II. His involvement in nuclear research within Germany's scientific establishment illustrates the moral dilemmas that scientists often face in times of conflict and underscores the potential societal consequences of scientific advancements. After the war, Hahn's regret over the destructive uses of nuclear fission and his advocacy against nuclear weapons reveal a conscientious individual grappling with the weight of his discoveries. His efforts, including his role in the Mainau Declaration, reflected his commitment to promoting responsible scientific progress, shaping him as a voice of caution during the dawn of the Cold War. As a foundational figure in nuclear chemistry, Hahn's legacy extends beyond his technical achievements, serving as a reminder of the responsibilities inherent in scientific knowledge and the enduring importance of advancing science with a strong ethical foundation.

5 List of Contributions

Amir A. Aliabadi received his bachelor's and master's degrees in Mechanical Engineering, in 2006 and 2008 respectively, from University of Toronto, Toronto, Canada, and his doctoral degree in Mechanical Engineering in 2013 from University of British Columbia, Vancouver, Canada. He is an assistant professor of engineering in the Environmental Engineering program at the University of Guelph, Canada. He is specialized in applications of thermo-fluids in buildings and the environment. Prior to this position he was a visiting research fellow at Air Quality Research Division, Environment and Climate Change Canada from 2013 to 2015 in Toronto, Canada, and a research associate in Department of Architecture at the Massachusetts Institute of Technology (MIT) from 2015 to 2016 in Cambridge, U.S.A.

Reza Aliabadi graduated from University of Tehran, Tehran, Iran, in 1999 with a master's in Architecture, and founded the "Reza Aliabadi Building Workshop". After completing a post-professional master's of Architecture at McGill University, Montreal, Canada, in 2006 and obtaining the OAA license in 2010, the workshop was reestablished in Toronto as atelier Reza Aliabadi "rzlbd". He has established a strong reputation in both national and international architectural communities. Local and global media have published many of rzlbd's projects. He has been invited to install in Toronto Harbourfront Centre, sit at peer assessment committee of Canada Council for the Art, speak at CBC Radio, give lectures at art and architecture schools and colleges, be a guest reviewer at design studios, and mentor a handful of talented interns in the Greater Toronto Area. He also had a teaching position at the School of Fine Arts at the University of Tehran and was a guest lecturer in the doctoral program at the same university. Artifice has recently published Reza's first monograph "rzlbd hopscotch". He maintains an ongoing interest in architectural research in areas such as microarchitecture, housing ideas for the future, and other dimensions of urbanism such as compactness and intensification. Beside his architectural practice, Reza also publishes a periodical zine called rzlbdPOST.

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Index

ISBN 978-1-7751916-7-4