THE WALK OF LIFE

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EDITED BY AMIR A. ALIABADI

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Biographical Essays in Science and Engineering

Volume 5

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One cannot escape the feeling that these mathematical formulas have an independent existence and an intelligence of their own, that they are wiser than we are, wiser even than their discoverers, that we get more out of them than was originally put into them.

—Heinrich Rudolf Hertz

Dedication

Laleh Sadraei

Preface

The essays in this volume result from the Fall 2020 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 Christiaan Huygens, Hermann Schlichting, Heinrich Rudolf Hertz, Erwin Schrödinger, Joseph-Louis Lagrange, and Abu Ali Sina. 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

Particular thanks go to my graduate student and teaching assistant for the course, Mohsen Moradi, who examined and evaluated the essays. I am also 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

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1 Christiaan Huygens (1629-1695)

The Unchallenged Polymath of Europe for Half a Century

By Bibiana Bartokova, Sarah Van Heyst, Fadi Katoola, Vanitha Mathur, and Ahmed Elmaghawry

1.1 Introduction

The interesting period in Europe between the death of Galileo in 1642, and prior to the rise of Newton, Christiaan Huygens stood unchallenged as the world renown scientist of that age. Christiaan Huygens is a well-known seventeenth-century Dutch scientist, mathematician, astronomer and philosopher (Bell, 1947). He was also devoted to music and arts, where he applied his musical talent to his scientific research (Bell, 1947). During a time where the human mind was focused on researching natural philosophy, Huygens was focused on studying applied mathematics, optical research and astronomy (Bell, 1947). However, during the later years in his life, he became interested in the natural philosophy of the universe. Through his research, Huygens made many contributions to the physical and natural sciences that have helped explain complex theories (Hockey, 2014). He was known for his discoveries in the wave light theory, the invention of the pendulum clock and for his contributions in understanding the nature of Saturn's ring (Hockey, 2014). Most of Huygens' career was dedicated to understanding the pre-existing relationship between mathematics and technology, which lead to new discoveries of our universe (Hockey, 2014).

1.2 Life of Great Wealth & Agony

Christiaan Huygens was born on the 14th of April 1629 in the Hague, Netherlands, to a wealthy family. He was the second son of five children to Constantijn Huygens and Suzanne Van Baerle (Hockey, 2014). Given that Christiaan's father was the highest ranking Dutch civil servant and secretary of state to several stadholders, Christiaan Huygens received a profound education from a young age. He was taught by private governors and tutors until attending Leiden University in 1646 for law and mathematics (Hockey, 2014). It was evident that Christiaan was becoming the most successful out of his siblings, in fact throughout his life his father called him "mon Archimède" (my Archimedes in French). Once in university he debated whether to pursue a diplomatic career or science and math but with some help from French philosopher and mathematician Marin Mersenne, Christiaan was encouraged to continue his studies in mathematics and science (Koehler, 2015). This served him well as by 1663 he was nominated as a fellow of the Royal Society. At this point in life, Christiaan was adamant about finding a paid scientific career and so his proud father aided in promoting him in France. By 1666, Huygens was nominated to enter the Academie Royale des Science which was a great honour (Hockey, 2014).

Although very smart and dedicated to his work, Christiaan had a medical condition that hindered him in many ways. Christiaan throughout his life suffered from debilitating headaches that made it hard to work, read, write, and meditate (Koehler, 2015). Many of his private journal entries and letters to siblings and cousins discussed how he struggled to write and respond to letters in a timely manner because of annoying and tormenting headaches and migraines (Koehler, 2015). He often asked for forgiveness and described how even though his suffering was great, he still felt obligated to respond. His headaches were getting so difficult that he sought out medical advice from a physician who had him purged and bled, which caused Christiaan to feel extremely ill to the point he was unable to leave his home (Koehler, 2015). Later on, he found a treatment that worked, he ended up drinking copious amounts of tea, stated by himself that he felt admirably well and in great pleasure (Koehler, 2015).

1.3 Huygens & the Pendulum Clock

Christiaan Huygens stood out in between the countless famous scientific minds of the 17th century. He possessed the highest order of intellectual and manual skills and has contributed greatly to the scientific and mathematical world. At 13 years of age, Huygens had built his own lathe, and at 17 years of age, he was able to discover Galileo's parabolic trajectory of a projectile as well as Galileo's time-squared law of fall. By the age of 24, he formulated the laws of elastic collision and discovered the ring of Saturn a year later, using one of his telescopes. Huygens made a substantial contribution to the improvement of timekeeping and the solution to the longitude problem (Matthews, 2000). In 1656 he was able to invent the pendulum clock, which was patented in 1657. Huygens' inspiration to invent the pendulum came from the investigations of pendulums conducted by Galileo. Galileo had started looking into the idea in the early 17th century and came up with the idea in 1637, where the pendulum was partly constructed by his son in 1649, but neither lived to finish it (Matthews, 2000). During that era, only the basic spring-driven table clocks were used for keeping time, but they were not very accurate as they were off by approximately 15 minutes every day. Huygens' pendulum, however, proved much more accurate at timekeeping than the table clocks and were able to reduce the loss of time by clocks from 15 minutes to approximately 15 seconds, increasing the accuracy by sixty folds (Matthews, 2000).

Moreover, the early spring-driven table clocks had wide pendulum swings that reached 100 degrees, due to their verge escapements, which made the pendulum inaccurate according to Huygens. He proved that wide swings led to the inaccuracy of the period and thus the rate of the clock. When clock makers realized that the only isochronous pendulums were the ones with small swings of a few degrees, they were motivated to invent the anchor escapement that reduced the swing of the pendulum to 4-6 degrees (Matthews, 2000). The anchor not only increased the accuracy but allowed the clock's case to accommodate for a longer time, slower pendulums, which caused less wear on the movement and required less power. Further improvements increased that accuracy, so much so that pendulum clocks dominated the timekeeping sector for hundreds of years, until the invention of the quartz clock in 1927 (Matthews, 2000).

1.4 Huygens' Psyche & Astronomy

Despite Huygens contributions to physics and mathematical treatises, he was also considered a philosopher and astronomer (Špelda, 2018). Huygens had a passion for astronomy as he would stare into the sky for hours to watch patterns of the stars (Špelda, 2018). This has led Huygens to introduce the idea of "Stargazer" (Špelda, 2018). In the book *Cosmotheoros* written in 1695 and published after his death in 1698, he explains that the universe is composed of many worlds that are inhibited by extra-terrestrial beings (Špelda, 2018). In the late years of his life, Huygens focused on philosophical rather than mathematical writings (Špelda, 2018). The word "Cosmotheoros" was invented by Huygens and was created to portray the relationship of a human being with the cosmos (Špelda, 2018). Therefore, "Stargazer" was introduced in the book as the ethical, epistemological, and cosmological definition of the teleological connection between a human being, God, and the cosmos (Špelda, 2018). According to this, Huygens explained the importance of stargazing as it incorporates the heavens of God (Špelda, 2018). He further explained that the examination of these heavens will lead a human being to the knowledge of God, the cosmos, and one's soul (Špelda, 2018). Therefore, this act was considered as one of the most valuable human activities that created a connection between one and the Gods (Špelda, 2018).

Huygens measured the size and distance of the planets relative to the Sun (Chapman, 1995). With the advancements he made to the Galileo telescope, he was able to track and look at the different planets in the sky (Chapman, 1995). He argued that all planets contain similar properties of planet Earth such as massy objects, and human-like inhabitants (Chapman, 1995). Through his research and stargazing strategy, he was able to discover a ring that orbits around the planet Saturn (Chapman, 1995). He estimated the thickness of the ring to be 4500 km (Chapman, 1995). Within his theory, Huygens believed that due to the presence of intelligent life on Earth, beings of similar intelligence could exist on other planets (Chapman, 1995). In addition, he hypothesized that the intelligence of these creatures would be similar to humans, not only in terms of creature instincts, but also the curiosity to learn and advance in nature, such as making tools and advancing in technologies (Chapman, 1995). As a result, these creatures would try to learn, and search for a greater creator (God) (Chapman, 1995). Due to his significant amount of work in astronomy, Huygens was considered to be of equal reputation to Descartes and Galileo, surpassing the discoveries that they had made.

1.5 End of Life & Legacy

After living in France under the patronage of Jean-Baptiste Colbert for 15 years, Huygens returned to Hague to recover from a severe illness in 1681 (Benson, 2010; Hockey, 2014). While he had planned on returning only for a temporary period of time, due to the political unrest between France and the Netherlands, Huygens was never able to return to Paris (Benson, 2010; Hockey, 2014). Huygens died in Hague in 1695 at the age of 66.

Outside of his revolutionary design of the pendulum clock and telescope, Christiaan Huygens contributed to many branches of natural philosophy and technology, including optical physics and dynamics, all while suffering from debilitating headaches. Huygens helped develop the wave theory of light, which explained reflection and refraction (Benson, 2010). While at the time Huygens' ideas were opposed by Newton's particle theory, both would eventually be combined to form the present-day quantum theory of light (Benson, 2010; Chapman, 1995). Huygens also discovered the isochronism of a cycloid and further developed the theory of evolutes which was presented in his paper *Horologium oscillatorium*. Published in 1673, this paper is recognized as a masterpiece of the Scientific Revolution. Additionally, the invention of Huygens' pendulum clock cemented the division of each day into equal hours, instead of being based on the movement of the sun, without which, modern day society would be incredibly different (Benson, 2010). During his life Huygens was viewed as an expert mathematician and physicist. In 1663 he was elected as a fellow of the London Royal Society (Hockey, 2014). Later, in 1666, he was invited by King Louis XIV to help form the French Academy of Sciences (Benson, 2010).

Christiaan Huygens is known to have been focused only on mathematical problems with physical application and meaning (Benson, 2010). He championed the importance of experimental work in scientific discovery as well as the use of geometric physics (Benson, 2010; Chapman, 1995). In history, the work of Huygens has been outshone by Newton and Leibniz due to their mathematical style of physics where differential equations and calculus are utilized (Benson, 2010). Because of the upcoming work of Newton and Leibniz, and the fact that Huygens would often withhold publications until years after he wrote them, the significance of some of his work was underappreciated (Benson, 2010). However, due to his major contributions to science and philosophy, Huygens is considered to be one of the most impactful mathematicians, physicists, and astronomers of the 17th century.

1.6 Conclusion

The value of education was instilled in Christiaan Huygens from a young age, which drove his energy to learning more about mathematics and science. Through this, his dedication, ambition and desire to learn increased, and led Huygens to provide significant contributions to mathematics, the telescope, and the design of the clock. His research and discoveries have had profound effects on scientific knowledge as his contributions have helped for the further research and innovations in mathematics, science and philosophy. His invention of the pendulum clock provided the society a more accurate way of telling time, which was more precise than the sundial (Benson, 2010). Moreover, the pendulum clock was also significant for astronomical observation and scientific experimentation (Benson, 2010). Huygens' recognition of Saturn's ring not only gave scientists a better representation of the planet, but also it began the inquiry of the nature of the ring that is still being researched today (Benson, 2010). This discovery also gave other scientists a clearer representation of the solar system. Huygens' wave and particle theories were combined and expanded to study all electromagnetic phenomena, which are significant components of modern quantum mechanics (Benson, 2010). Overall, Huygens' major contributions in the 17th century have not only impacted the innovations of scientists thereafter, they have also contributed to the theories used today.

2 Hermann Schlichting (1907-1982)

Rebuilding of the German Aeronautics Industry Twice

By Kiersten Bell, Luca-Bogdan Burlacu, Tabitha Gaynor, Sejal Mistry, and Emily Snoei

2.1 Background & Education

German scientist, Hermann Schlichting, made great contributions to the field of fluid mechanics and airplane aerodynamics. He was born in Balje, Germany, on September 22, 1907, and passed away June 15, 1982, at age 74. At Universities of Jena, Wien, and Göttingen, Schlichting studied mathematics, physics, and applied mechanics, respectively (Hummel et al., 2009). It was at the University of Göttingen in 1930 that Schlichting earned his doctorate under the supervision of Professors Ludwig Prandtl and Albert Betz, and completed the government test to become a mathematics and physics teacher (Hummel et al., 2009). Under Prandtl and Betz, Schlichting wrote his thesis on the free turbulence in a wake (Oswatitsch and Wieghardt, 1987) titled *Über das ebene Windschatten problem*. His advisor, Prandtl, who was known as the father of modern aerodynamics, had a significant influence on Schlichting and the work he would later pursue in both fluid mechanics and aerodynamics.

2.2 Work Prior to World War II

Prior to World War II (WWII), Schlichting focused his career on boundary-layer research. From 1931 to 1935 he worked under the direction of Professor Prandtl at the Kaiser-Wilhelm-Institut für Strömungsforschung in Göttingen. There, Schlichting focused his research on viscous flows, boundary-layer control, and boundary layer on rough surfaces (Hummel et al., 2009).

One of Schlichting's most important findings from his boundary-layer research was on laminar-turbulent transitions (Hummel et al., 2009). He was able to continue the work of Tollmien; another doctoral student under Prandtl (Eckert, 2017). Tollmien had derived an instability diagram for a flat plate with special plane flow close to the laminar boundary region (Eckert, 2017). This became an important diagram for stability theory (Eckert, 2017).

Schlichting furthered Tollmien's instability diagram by determining curves for unstable waves (Hummel et al., 2009). He also incorporated amplitude distribution for some neutral waves in order to analyze disturbances (Hummel et al., 2009). This allowed him to find the streamline pattern of perturbed flow (Hummel et al., 2009). A final adjustment that Schlichting made to the instability diagram was the addition of pressure-gradient parameters (Hummel et al., 2009). He found that with a positive pressure gradient, wave instability increased, whereas stabilization occurred with negative pressure gradients (Hummel et al., 2009). The work of both Tollmien and Schlichting enabled calculations of stable boundaries and perturbed flows to be made (Eckert, 2017). Thus, this theory regarding the stability of flow in laminar-boundary layers became known as the Tollmien–Schlichting instability (Eckert, 2017). Today, these perturbations (waves) are well known as T-S waves in fluid dynamics (Hummel et al., 2009).

2.3 Work During World War II

A major event that occurred during Schlichting's life and upturned the scientific community was WWII. Scientists began emigrating out of Germany even before 1933, when Adolf Hitler was appointed Chancellor of Germany, and the situation became more dire thereafter (Siegmund-Schultze, 2009). So began the Scientific Exodus, when over 100 scientists emigrated from Germany out of necessity, either because they were Jewish or afraid of the political direction that Germany was taking. Schlichting did not emigrate with the other scientists, and it is not known why he stayed (Siegmund-Schultze, 2009). Since there is no indication that he was Jewish, perhaps he was not a target of Nazis and was able to continue his work as normal. However, this would require tolerance of the Nazism. Alternatively, like his advisor, Ludwig Prandtl, perhaps he shared nationalistic views and believed in the climate overtaking Germany (Siegmund-Schultze, 2009).

Shortly after Hitler's rise to power in 1935, Schlichting switched from the study of boundary-layer theory to aerodynamics, and began working in industry at Dornier (Hummel et al., 2009). Here, Schlichting designed and built his first wind tunnel, which was used to test the aerodynamics of model airplanes (Hummel et al., 2009). The significance of this work is that Dornier manufactured airplanes, several of which were used by the German air force, Luftwaffe, to fight the Allies in WWII. Does this indicate that Schlichting did support Nazis? Not definitively, as he left his position at Dornier after only two years (Hummel et al., 2009).

In 1937, Schlichting became the Director of the Institute of Aerodynamics at the Technische Hochschule Braunschweig, as well as professor of flight mechanics (Hummel et al., 2009). In this position, again he designed and constructed a low-speed wind tunnel that he used to further study the interference of wing fuselage and empennage, high lift behavior of swept wings, and laminar airfoils (Hummel et al., 2009). His theory-based work on laminar airfoils has been especially impactful, laying the foundation for modern sailplanes and business aircraft, as well as future airplane adaptation to climate change. For his work and research on the design of laminar airfoils, Schlichting was awarded the Lilienthal-prize of the Lilienthal-Gesellschaft (Hummel et al., 2009).

Although Schlichting's academic research does not seem to be directly related to warplanes or weaponry (Hummel et al., 2009), it is difficult to imagine that Schlichting could assume a powerful position at a German university during this time without being in some way associated with the war effort. Especially since the majority of German research in aerospace and aeronautics during this time was likely aimed at advancing warfare given the amount of funding and support by the German government (Dawson, 1991). Furthermore, the secret German airplane and aircraft testing facility, Luftfahrtforschungsanstalt, or the Aeronautical Research Institute, was located in Braunschweig nearby the Technische Hochschule Braunschweig. The testing facility and the university were known to have exchanged personnel, including Hermann Schlichting and his colleagues

(Dawson, 1991).

Scientists who emigrated from Germany maintain that those who stayed, like Schlichting, most likely disagreed with Nazism internally (Hummel et al., 2009). If there were moral obligation to rebel against Nazis, which it should be noted that there is no publication indicating Schlichting fulfilled this duty, then he was fatefully punished for this later, as discussed in the following section. It seems that above all, Schlichting was dedicated to academics, supervising a doctorial exam just hours before the Allies arrived (Hummel et al., 2009).

2.4 Work After World War II

Under the Potsdam Agreement 1945, the Allied nations laid out a plan on how to reconstruct and occupy Germany after the war. Under this agreement Germany was divided into four military occupation zones, each occupied by either the Americans, British, French, or Soviets, to establish and maintain control. In addition, there was the complete disarmament and demilitarization of Germany, which involved dismantling any industry that had military potential. Furthermore, the German educational system was to be purified of any Nazi ideology and influences. As a result, restrictions on Research & Development (R&D) and vehicle manufacturing were put into place across the country (Hummel et al., 2009).

Specific to Schlichting, the area of aeronautical research was significantly impacted as all aeronautical R&D facilities were dismantled and destroyed (Hummel et al., 2009). Specialized facilities like the wind tunnels Schlichting designed and worked with, were demolished, with only a few left solely for vehicle aerodynamic research purposes (Hummel et al., 2009).

Although the Allied nations prevented further German research into the field of aeronautics, they still valued their work, and ordered German scientists to summarize and hand over all of their research (Hummel et al., 2009). Schlichting was one of these scientists, summarizing his work in the field of aerodynamic interferences of parts of the airplane (Hummel et al., 2009).

Since his area of research was no longer allowed, Schlichting moved on to study cascade-aerodynamics of turbines and compressors, and vehicle aerodynamics for the time being (Hummel et al., 2009). Years later, when restrictions began to ease and research into aeronautics was permitted, Schlichting resumed lecturing at the Technical University of Braunschweig, whilst also assuming the director position at the DFL Institute of Aerodynamics in Braunschweig, and the director position of the AVA in Göttingen in 1956 (Hummel et al., 2009).

2.5 Rebuilding the German Name in Aeronautics

Years after Germany's defeat and occupation, the country saw the beginnings of unity once again with the formation of the Bundesrepublik Deutschland (Federal Republic of Germany), and marked the notion that Germany would once again enter the field of aeronautics (Hummel et al., 2009). The first step in Germany's return, was to re-establish its research facilities, and Schlichting was one of many who helped to plan and construct these new wind tunnels (Hummel et al., 2009). Limited funding prevented the construction of the large-scale facilities they had before the war, but Schlichting, the optimist he was, saw this as a wonderful opportunity (Hummel et al., 2009). The war had devastated the aeronautical research field, many of the promising minds at the time were either dead, or had relocated far away from Germany, thus, the need to inspire, teach, and build the new generation of aeronautical research and engineering minds was now (Hummel et al., 2009). Schlichting recognized that having multiple smaller facilities was an advantage as it allowed them to be dispersed throughout the country, allowing them to reach out to inspire and expand the knowledge of a larger portion of the population (Hummel et al., 2009).

By 1953 the research and aircraft industry were back in motion, and Schlichting began to write a new textbook, *Aerodynamik des Flugzeuges* (*Aerodynamics of Airplanes*) with colleague E. Trunkenbrodt, in preparation for the recommencement of lectures at the Technical University of Braunschweig (Hummel et al., 2009). This book was a major update to existing textbooks in airplane aerodynamics as it incorporated all the drastic and innovative leaps that occurred during the war and Schlichting's pre-war findings (Hummel et al., 2009). With research facilities up and running, lectures back in session, and a new comprehensive textbook, the aeronautic students of Germany had all the resources they needed to make their grand return to the field of aeronautics.

As for Schlichting, he received many awards for his work and research in the field of aeronautics. These awards include the 50th Anniversary of Powered Flight medal from the National Aeronautical Association in 1953, the Ludwig-Prandtl-Ring of the Deutschen Gesellschaft für Luft - und Raumfahrt (German Society for Aeronautics and Astronautics) in 1969, among several others (Hummel et al., 2009). Schlichting was also a member of the Advisory Group for Aerospace Research and Development (AGARD), who awarded him with the Von-Kármán-Medal, its highest honour, in 1980 (Hummel et al., 2009).

2.6 Lasting Impacts

Revitalization of the aircraft industry and aeronautical research in Germany began in 1953 (Hummel et al., 2009). With the continuation of lectures, the lack of improper textbooks on the fields of airplane-aerodynamics proved to be of major concern (Hummel et al., 2009). The Springer-Verlag, a German multinational publisher of books, offered Schlichting to write the epitome of all aerodynamic textbooks (Hummel et al., 2009). An act of cementing his legacy, with the help of E. Truckenbrodt, Schlichting produced a two-volume textbook *Aerodynamik des Flugzeuges* (*Aerodynamics of the Airplane*), of which became the standard textbook in the field of airplane-aerodynamics for many years (Hummel et al., 2009). In 1982, Schlichting published another book, Grenzschicht-Theorie (Boundary-Layer Theory). Both of his textbooks appeared in 11 editions and translated into 5 foreign languages, enabling an incredible number of students worldwide into the insight of fluid dynamics (Hummel et al., 2009). Including his scientific research, of which was documented more than 100 times in published works, Schlichting guided over 100 students over the course of their doctorates, and 10 academic lecturers on their thesis (Hummel et al., 2009). Although gone, Schlichting and his contributions to science and engineering will never be forgotten. He will forever be cemented in our world through his publications and the many minds he inspired during, and well past, his lifetime.

3 Heinrich Rudolf Hertz (1857-1894)

The Father of Frequency

By Alexia Pittas, Vivi Tran, Noah Trembley, Albert Shehata, and Silas Wauben-Scott

"One cannot escape the feeling that these mathematical formulas have an independent existence and an intelligence of their own, that they are wiser than we are, wiser even than their discoverers, that we get more out of them than was originally put into them." – Heinrich Hertz (Bell, 1937).

3.1 Early Life

Heinrich Rudolf Hertz was born in Hamburg, Germany, on February 22, 1857. At this time, remnants of the Holy Roman Empire of the German Nation, which had dominated Europe for nearly a millennium, left Germany divided by a land of feudal kingdoms (Kraus, 1988).

Born into a wealthy and cultured Hanseatic family, Hertz was the oldest of his three brothers and one sister. His grandfather, Heinrich David Hertz, was a scion of a prosperous Jewish family; and his grandmother, Betty Auguste Oppenheim, was the daughter of the banking family in Cologne. His father, Gustav Ferdinand Hertz, was a writer and then was later elected as minister of justice in the Hamburg's senate; and his mother, Anna Elisabeth Pfefferkorn, was the daughter of a Prussian army surgeon and descendent of the Frankfurt burghers (Süsskind, 1988).

As a boy, Hertz displayed many unusual talents; he made all kinds of drawings and handcrafts and even familiarized himself with operating machine tools and lathes that required precision (Kraus, 1988). He had an intense curiosity about how things worked in the material world and built scientific instruments. He also studied Greek and Arabic and was interested in the arts and sciences. Such topics included psychology and Darwinism (Kraus, 1988). At the age of eleven, Hertz studied drafting on Sundays at Gewherbeschule, an industrial high school. His parents recognized his talents at a young age, so he was placed in a curriculum that focused primarily on arithmetic and natural sciences. Although his mother and father had hoped for him to become a construction engineer, Hertz love for mathematics and physics was undeniable.

3.2 Education

According to research by Süsskind (1988), Hertz at the age of 17, initially did not attend university but sought out a career in engineering in Frankfurt, Germany. During his time as an apprentice, he attempted to create a self-registering telegraph and then later enrolled in the Technical University. Here he found that the school did not provide him enough mental stimulation, so he opted out after a year and completed a 12 months of compulsory military service (Süsskind, 1988).

Later in 1877, Hertz enrolled in the University of Munich where he felt compelled to study experimental physics, where after being enrolled for only one year he progressed quickly when in a laboratory environment. However, he decided to leave Munich and pursue other ventures at Berlin University to continues his studies under the internationally famous professors, Hermann von Helmholtz and Gustav Robert Kirchhoff (Süsskind, 1988). Research done by Ramsay (2013), states that Helmholtz recognized his pupil's talent in first year and made Hertz his teaching assistant at the school. In Helmholtzian Laboratories, Hertz was driven by his mentor's fascination of bringing electrodynamics and conservation of energy together to develop his own theories of electromagnetics (Ramsay, 2013). When Helmholtz posed a philosophical physics challenge to his department urging them to find if electric current possesses inertia, Hertz took on the opportunity to prove himself to his mentor (Ramsay, 2013). In 1879, he had won first place prize for his investigation on the topic and was highly praised by many professors at the school. His work was published in *Annalen der Physik und Chemie*, along with papers containing work from other famous physicists including Weber, Kundt, and Siemens (Süsskind, 1988).

After only completing three semesters at the school Hertz was given special consideration to take an oral examination to graduate. He passed his final examinations with the distinction magna cum laude (Ramsay, 2013). Later, he continued to work under Helmholtz where he was challenged with conducting an experiment that would demonstrate if a time varying electric field would produce a magnetic field. Instead, Hertz realized this would be too challenging, so he decided to show that conductors that were constantly rotating produced induction. Upon completion of his research, it was published in *Annalen*

(Süsskind, 1988). Afterwards, Hertz worked at the university for three more years researching theoretical thermodynamics, meteorology, and elasticity. His breadth of knowledge lead him to pursue new ventures at Kalshrue Physical Institute where he became the professor of physics and began his famous experiments on electromagnetic waves (Ramsay, 2013).

3.3 Contributions to Physics

Having an astounding and diverse background in his education lead Hertz to formulating multiple contributions to modern day Physics. Some of his discoveries include the creation of the first radio transmitter and receiver, defining displacement current, standing waves on wires, the skin effect and standing waves in air, beaming, reflection and refraction and polarization, and the Hertz vector and apparatus (Kraus, 1988).

Hertz proved Maxwell's theory of the relationship between electric and magnetic fields through experimental analysis. He did so by using two flat induction coils and a capacitor discharged through one coil to create a spark on the upper portion of the loop (Kraus, 1988). Hertz introduced a straight wire $\lambda/2$ dipole which indicated an open resonant system, whereas all other previously conducted tests used a closed resonant system. Then, to create resonance, the single-turn loop was adjusted to a desired length producing a variety of wavelengths. This resulted in the first dipole antenna having a loop receiver to be classified as the first radio system.

Another notable contribution from Hertz is displacement current ($\partial D/\partial t$). He was able to prove that displacement currents exist through current carrying effects between paraffin blocks and metal sheets because they were able to produce similar radio waves (Kraus, 1988). Further, Hertz was able to determine the wavelength by creating standing waves on a straight wire and measuring the distance between the two wires multiplied by a factor of two.

Also, the skin effect was demonstrated by using a long wire enclosed in a parallel metal cage which yielded no current flow along the line when the cage closed around the ends of the wire (Kraus, 1988). Moreover, to observe standing waves in air, Hertz used a flat zinc plate and his dipole transmitter along with a resonance loop to create interference between apparatuses to produce a standing wave.

Hertz utilized a parabolic reflector for transmitting the waves for beaming. Also, he realized that he would need to possess another full wavelength dipole equipped with a similar parabola for comparison purposes. He was able to generate parabolas as well as angles of reflection and incidence using a zinc sheet. Moreover, indexes of refraction were discovered by using an asphalt prism placed between parabolas to measure the angle of incidence (Kraus, 1988).

Hertz was able to demonstrate linear polarization by changing one of the parabolas to lie horizontally and implementing a grid of vertical wires between the parabolas so that different responses were observed. Said wires behaved as atomic lattices of calcite crystal being exposed to light, for comparison (Kraus, 1988).

Also, the Hertz Vector represented by Π was determined by using the distance called r between both the electric and magnetic fields and involving the current density. Its main use pertains to electromagnetic radiation. It is quite immaculate that Hertz was able to make such discoveries using an apparatus of such size and extent, especially during this time period. Presently classes that explore radio waves and modern laboratories include smaller and more acceptable apparatuses to conduct Hertz's experiments.

3.4 Late Life

After writing 15 papers at the Berlin Physical Institute from 1880 to 1883, Hertz had to decide between taking his mentor's job as a Professor, or move to Bonn to focus solely on research. During his time in Berlin, he fell in love with one of his colleagues' daughter, Elizabeth Doll, and married her in 1886. Together they had two children named Johanna and Matilda, who later went on to become a notable biologist. His daughters never married, so Hertz had no descendants.

Hertz chose the professorship at Bonn University in 1889, however, he began suffering from debilitating migraines and complained of tooth aches. This led to him opting to have all his teeth removed in 1889 to hopefully cure his chronic condition. Unfortunately, the migraines returned in later years, and included aching in the nose and throat. With the pain worsening he was no longer able to work, so he sought constant differing treatments, but nothing seemed to help his ailments. He lectured until December 7th, 1893, however, his migraines returned requiring him to go through with another medical procedure. Unfortunately, on January 1st, 1894, the date of his last operation, he succumbed to surgical complications at the age of 36. It was not until his death that his condition was discovered to be a malignant bone disease.

3.5 Awards and Legacy

As a result of his scientific work, Heinrich Rudolf Hertz was honoured through many ways by countries around the world from as early as his years as an undergraduate student. He became the assistant to one of his professors Hermann von Helmholtz which was incredibly rare for someone of his age at the time (Süsskind, 1988). Furthermore, his academic prowess was awarded by being given permission to graduate with his bachelor's degree despite not completing his final two semesters. He also passed his final oral examination with summa cum laude which is the highest possible graduating distinction that can be achieved (Süsskind, 1988).

Perhaps the way most people know of Hertz was through unit of frequency, Hertz (abbreviated as Hz), referring to the number of times an event repeats itself each second. This International Systems of Units (SI) name was chosen by the International Electrotechnical Commission in 1930 to honour the "father of frequency". This unit replaced the previously used cycle per second, or cps as it was abbreviated (Ramsay, 2013).

In 1987 the Institute of Electrical and Electronics Engineers (IEEE) created the Heinrich Hertz Medal to honour his achievement in the field of radio waves (Ramsay, 2013). His legacy was also reverenced through postal stamps around the world which featured a depiction of his face. Additionally, a crater behind the eastern limb of the moon formerly known as Crater 200 was named after Hertz in 1961 (Kraus, 1988).

The work of many outstanding scientists goes unnoticed outside of the scientific community due to the general public being unable to discern a direct connection between how those discoveries affect their lives. However, in the case of Hertz, it is difficult not to notice how his work has impacted our lives due to the fundamental relationship his work has with many technologies we have become accustomed to today. We would be unable to enjoy inventions such as mobile telephones, radio, and televisions if it were not for the discoveries made by Hertz (Ramsay, 2013).

3.6 Reflection

Hertz exemplified the qualities of a great physicist through his love for mathematics and physics, even at a young age. Despite his health struggles and death at an early age, he was able to pave the way for telecommunication and electronic devices that humans use every day. He dedicated his life to research and his discovery of electromagnetic waves has made an outstanding contribution to science. As a result, the key outcomes of his work are known by many simply by virtue of his name, and he has been honoured extensively through academic exemptions, awards, postal stamps and even a moon crater.

4 Erwin Schrödinger (1887-1961)

A Great and Complicated Man

By Melanie Weisenberg, Megan Beauchamp, Nina Sattolo, Leah Weller, and Faye Perchanok

4.1 The Physicist

On Friday August 12th, 1887 in Austria's capital Vienna, a Nobel prize winner was born. Throughout his education, Erwin Schrödinger was always passionate about the sciences as well as ancient grammar and poetry. As a young man, Erwin studied at the University of Vienna focusing on and collaborating with his advisor Fritz Hasenöhrl's work. Following his time at this institution, he progressed to the University of Zürich for six years where he mastered theoretical physics, specific heats of solids, thermodynamics, and atomic spectra. Eventually, the physiological studies of colour became the focal point of his research and with that he made a name for himself as a physicist.

In 1925, towards the end of his time in Zürich, Erwin began exploring a thesis written by Louis de Broglie. This paper proposed the theories on wave mechanics that lead to the discovery of the famed Schrödinger wave equation. This equation is a linear partial differential equation that describes the state of the system at each spatial position as well as the wave probability for the motion of small particles and how these particles can be affected by external forces. The equation is based on a method of Eigen Values and the sum of an infinite series. The equation assumes that matter and the electrons can be both particles and waves. The equation is used in chemistry and physics that deal with problems regarding atomic structure of matter.

After his time in Zürich, Erwin moved to yet another school now as an established physicist in the field of quantum physics. He stayed at the University of Berlin for 6 years until 1933, when Adolf Hilter became the leader of the Nazi party. From there he joined the University of Oxford for 3 years and became the head of the School for Theoretical Physics at the Institute for Advanced Studies in Dublin. Erwin was more than just a Nobel prize winner, he was a veteran, a philosopher, an author, and a cat lover.

4.2 The Cat Lover

Ironically, Erwin's legacy is mainly attributed to an imaginary experiment involving a cat. In 1935, while working with Einstein, Erwin found himself disagreeing with the Copenhagen interpretation of quantum mechanics (Wimmel, 1992). Based off Niels Bohr and Werner Heisenberg writings, this interpretation states that microscopic level materials do not have a definite state prior to observation. The properties of the material, which are defined by the conscious observer, before the measurement are ambiguous.

To illustrate his point, he wrote a paper detailing a sealed box with a cat, a Geiger, a radioactive substance, and poison (Wimmel, 1992). In this experiment two scenarios of equal likelihood could unfold; the radioactive substance will either decay or it will not. Radioactive decay would trigger the Geiger, a device that measures radiation, to release the poison thus killing the cat. If the substance does not decay, the Geiger is not triggered, and no poison is released. Without emitted poison the cat is safe and alive. Would you ever describe something as simultaneously alive and dead? No, it is impossible to be both alive and dead. This is the argument Erwin was trying to illustrate. Shakespeare would have been proud; the saying is to be or not to be, you cannot be and not be at the same time. Erwin's point was made, the cat was either dead or alive whether it was observed at the time of occurrence or later when the box is unsealed.

Schrödinger's cat paradox is presently famous and ingrained in pop culture. In an episode of the popular TV series Silicon Valley a character exclaims "Does that mean that all of us who attend open casket funerals are murderers?". The imaginary experiment once again taught its lesson, the person was dead before it was observed! John Lennon's son wrote a song with the lyrics "Can't be sure that I exist when you are not around". The song is titled Schrödinger's Cat (Crease, 2015). Would Erwin be happy with this being the most prominent part of his legacy? Or was he just trying to prove a point to his colleagues?

4.3 The Philosopher

Although Erwin was most famous for his thought experiment involving the cat, he was also highly recognized for his contributions to virtually every field of science. Incredibly intellectually versatile, Erwin studied physics, mathematics, biology, history, and philosophy. His bountiful career took him all over Europe, including Austria, Belgium, Great Britain, and Italy. After many years of moving around, in 1940 Erwin settled down at the Dublin Institute for Advanced Studies, where he accepted the position of Director for the School of Theoretical Physics. Erwin reflects on the fifteen years he spent in Dublin as a wonderful and happy period in his life. During those years, he continued his scientific research, publishing various papers on gravitation and electromagnetism. However, his focus also expanded to include philosophy, and he began publishing literature on consciousness, free-will, and his theory of life (Götschl, 1992).

Like other well-known physicists of the time, Erwin was not satisfied with the accepted interpretations of quantum theory, and he expressed doubts regarding the philosophical relevance of these orthodox solutions (Götschl, 1992). This was not the first time Erwin had expressed a need for deeper philosophical understanding; his life-long interest in ancient Greek history and philosophy, summarized in his 1954 publication *Nature of the Greeks*, heavily influenced his views on the relationship between science and metaphysics. Erwin's 1961 book, *My View of the World*, explored consciousness in terms of self and the world through the lens of Vedantic philosophy. As described in *My View of the World*, the plurality perceived by individuals is only an appearance; the external world is made from the sensations and perceptions of the self. This basic pillar of Vedanta heavily influenced Erwin's philosophical beliefs. He believed individuals (the self) are aspects of a universal spirit, and the common experiences perceived in the external world resulted from the unity of individual consciousness (Götschl, 1992). Bridging ancient Greek philosophy to modern science to Vedanta, Erwin's vast philosophical beliefs were considered to have a great impact on the world's view of modern philosophy

(Götschl, 1992). With his immense contributions to nearly every field of science, Erwin remains one of the most important scientists and philosophers of his time.

4.4 A Father of Genetics

Erwin's interests extended beyond just physics and philosophy. He also had an impact on biology as well as psychology. His studies and works in these fields were inspired by his philosophical focus on the principal of orderliness.

During those 15 years that Erwin lived in Ireland, he also published a book entitled What is life? based on lectures he gave at Trinity College. In this book, he discusses how quantum physics can be used to explain the stability of genetic structure. At the time of the book publishing, it was thought that proteins carried the hereditary material in the body. Erwin, however, countered that the genetic material had to have an aperiodic structure, that is a non-repetitive molecular structure (Symonds, 1986). He was the first to suggest that genes contained some form of a "code-script" with the genetic information. The following year, in 1944, Oswald Avery published evidence that DNA was this genetic material. However, there was a problem. DNA was thought to be a boring molecule with repetitive structure, which was directly contradictory of what Erwin claimed. In 1947, Erwin Chargaff suggested that the change in "bases" of the DNA molecules could have far reaching implications. It wasn't until ten years after Erwin's book was published that the mystery was solved. James Watson and Francis Crick published their second article on the structure of DNA where they proclaimed that the precise sequence of the bases is the code which carries the genetic information. And so, biology was never the same afterward.

Erwin also contributed a great deal to psychology, specifically early colour theory. The study of colour has been a topic of interest for both philosophers as well as physicists for years. Erwin himself showed great interest in the study of colour throughout his life and published several papers on the topic. One of his greatest contributions was his connection of the two prevailing color continuum conception theories at the time. The first was the Young-Helmholtz trichromatic theory, which is based on the idea that the visual system responds to three colors and that the colours viewed are a result of the combination of differential responses of these three components. The second was the Hering opponent-process theory, which differs in that the visual system is believed to respond to three pairs of colors and the combination response of these pairs, resulting in color vision. The two theories were believed to be uncorrelated until Erwin showed that the two were connected through a transformation of the color plane (Niall, 2017).

4.5 A Good Man

Erwin's academic contributions were put on pause a few times during his career. As the Great War, or World War I (WWI) as it is commonly known, began to take place in 1914, Erwin felt a patriotic duty to serve. The war began following the assassination of the Austrian Archduke Franz Ferdinand, in Erwin's home country. As Austria-Hungary declared war on Serbia, Erwin put a pause on his academic endeavours, serving as an artillery officer for his country, where he provided indirect fire support, air defence, and surveillance and target acquisition in battle.

Following his service to his country, Erwin settled in for a more pleasant and peaceful career in academics at the University of Zürich. He has said that these years were some of his happiest, in the company of wonderful friends and colleagues, which coincide with his most engaging academic years, working heavily on topics on theoretical physics. It was at the end of his indulgent academic pursuits of the 1920s that he came up with what is now known famously as the Schr"odinger wave equation.

Following this great discovery, Erwin moved to Germany to be at the center of many hot academic pursuits occurring during this time. In Berlin, he was in his element, taking part in weekly colloquies with fellow colleagues. However, as Hitler rose to power, he grew weary of Germany and felt he must flee before the war erupted. He first tried to continue his career in England, but his home sickness for Austria eventually brought him back to his home roots, where he took a position at the University of Graz. As the war progressed, Austria was annexed, and his leaving Germany was not well taken, so he fled to Italy, then moved safely about some other parts of Europe before finally settling down in Dublin.

Erwin's career was successful, but not without political turmoil. This was a difficult time for many, the constant stress of Nazi oppression and fear of safety was ever present. He vocalized his opposition to Nazism, a dangerous statement, which led to his dismissal at the University of Graz, harassment from colleagues, and threats to not leave the country. Ultimately, he felt fleeing to Italy would provide more safety for him and his beloved. From there he moved to Dublin, where he remained untouched for the remainder of the war.

His final days were in post-war Austria, where he passed away from tuberculosis, an infectious disease which he had contracted several times in his youth. His legacy lives on in the scientific community, and he is remembered not only as an astounding physicist and all-around academic, but as a good man, with a strong heart to complement his astounding brain.

5 Joseph-Louis Lagrange (1736-1813)

The Complement of Leonhard Euler

By Alex Goulden, Eric Grimminck, Evan Chatfield, and Nolen Beattie

5.1 1736 to 1766: Early Years, Life in Turin

Joseph-Louis Lagrange was born on January 25, 1736 in the kingdom of Sardinia, now northern Italy, in the city Turin (Caparrini, 2014). He is Italian-born, baptised in the name Giuseppe Lodovico Lagrangia, and according to the Italian encyclopedia (Italian Encyclopaedia) he is an Italian mathematician and astronomer (Caparrini, 2014). Lagrange had French ancestors, which influenced him to turn more toward his French background where he started to sign his name in the French form and eventually naturalized to French. This caused many debates between Italians and the French who both claim Lagrange is from their side of nationality. His father was treasurer of the Office of Public Works and Fortifications to the King of Sardinia and his mother was the only daughter of a medical doctor.

Together they had 11 children but only two survived to adulthood, one of which being Lagrange (Caparrini, 2014). Lagrange didn't come from a wealthy family even with his father's position due to his father losing large amounts of money from poor financial investments.

Initially, Lagrange wasn't interested in the topic of mathematics and leaned more toward classical Latin as he found "Greek geometry rather dull". This caused him to follow in the path his father planned for him, which was for Lagrange to become a lawyer at the College of Turin. While at the college, he frequently went to the library and started to read works by famous mathematicians and physicists among the likes of Wolf, Newton, Euler, and Halley. Halley's work on algebra being used in optics caught his attention and led him to attend teachings at his college by Beccaria. From all this, he gained a keen interest in mathematics and physics and decided to pursue mathematics instead of law. This decision may not have happened if his father never lost the money as according to Lagrange himself, "If I had been rich, I probably would not have devoted myself to mathematics," and the world of mathematics would have lost out on one of the most influential mathematicians of the 18th century.

Lagrange was mainly self-taught without guidance from top mathematicians, but this didn't stop him. After only one year of self-study he became the assistant professor of mathematics at the Royal School of Artillery and Fortifications (Pepe, 2014). This didn't last long as he realized he was more of a theorist than an educator. After making a few discoveries from reading published works, Lagrange wrote a letter to the greatest mathematician at the time, Leonhard Euler, discussing his ideas on the Calculus of Variations. Euler was thoroughly impressed with Lagrange's work to the point that he held back his work and worked together with Lagrange to let him publish his work on the Calculus of Variation first (Pepe, 2014). Euler also recommended Lagrange for membership in the Berlin Academy when he was only 20 years old (Pepe, 2014). This teacher-pupil relationship with Euler propelled Lagrange and gave him both confidence and international rapport, allowing him to create the Private Society, which focused on research to publish journals (Pepe, 2014). This group later evolved into the Royal Society and eventually the Royal Academy of Sciences (Pepe, 2014). Here Lagrange was able to further apply his knowledge of mathematics and create many new ideas in the study of math and physics.

5.2 1760s: Lunar Liberations

Beginning in the 1760s, Lagrange cultivated an interest in an entirely new form of mathematics, celestial mechanics (Although Laplace would not coin the term “Celestial Mechanics” until 1798) (Laplace, 1829). His work in the field began in 1755, when a 19 year-old Lagrange coined the methods used in calculus of variations (Fraser, 1983). Building off his prowess for optimization, in 1760 and 1761 he formally published methods and solutions for finding maxima and minima. These essays contained the mathematical generalization proving Euler's treatise on *Variational Calculus*, and made the principle of least action the basis of dynamic calculus (Fraser, 1983). The principle of least action enables mathematicians to derive the equations of motion for a system, by proving that the derivative of an action is stationary to the first order (meaning not time dependent) (Fraser, 1983). By this time in his career it was already said that Lagrange was among the greatest living mathematicians

(Fraser, 1983).

In 1762 the Paris Academy of Sciences proposed a prize for an explanation as to why the Moon always presents slight variations of the same face (Fraser, 1983). This problem is known as Lunar Libration, whereby due to the Moon's axial tilt, orbit and rotational speed, Earth is only ever presented with little over half of the Moon's face. It had been previously attempted by the likes of Newton, Cassini, and D'Alembert to no avail, before Lagrange (Fraser, 1983). By combining his statical rule of virtual velocities and D'Alembert's principle, he was able to form a new foundation for his future mechanical analytics (Fraser, 1983). This later formed the basis of his groundbreaking treatise *Mécanique analytique* (Fraser, 1983). By solving this long standing problem, Lagrange won the 1764 Paris Academy of Sciences prize, earning him fame and fortune. He also went on to win the same prize for similarly important breakthroughs in 1772, 1774, and 1778.

His intrigue in celestial mechanics culminated in the creation of multiple novel principles and the solution to the "Three Body Problem" (Pepe, 2014). Owing to his interest in optimization, and building off of Newton's laws of motion and his law of universal gravity, Lagrange discovered what has come to be known as "Lagrange Points". Lagrange points are locations in space where gravitational forces between two large masses are equal to the centripetal force required for a small object to orbit with them. His solution to this problem, known as the Three Body Problem, whether this was recognized by Lagrange at the time is unknown; however, the importance is immeasurable for today's astronomers. There are 5 Lagrange points in the Earth-Sun system. Point $L1$ contains NASA's Solar and Heliospheric Observatory Satellite. Point $L2$ is home to the European Space Agency's satellite Planck, and it will be the future home of the

James Webb Space Telescope.

5.3 1780s and 1790s: Living through the French Revolution

Lagrange was living in Paris throughout the French Revolution, so it's no surprise that the Revolution shaped much of his personal and professional life at that time. The first major impact the revolution had on Lagrange's life was during the "Reign of Terror" in 1793. Lagrange was an elite foreigner at a time where the executions of elites and the arrest of foreigners was widespread. Lagrange was exempted from the arrests when Antoine Lavoisier, an influential French chemist and close friend of Lagrange, intervened and convinced the new French government to grant him an exception. Tragically, Lavoisier himself was executed after being falsely accused of defrauding the government as a tax collector. Lagrange was devastated and appalled by this and wrote, "It took only a moment to cause this head to fall and a hundred years will not suffice to produce its like".

In addition to affecting his personal life, Lagrange's professional career was also shaped by the societal changes brought on by the French Revolution. One of the main ideals of the French Revolution was education, the people inspired by enlightenment values of logic and reason. Living in a society with a new and intense focus on education influenced Lagrange to restart teaching and writing about his mathematical innovations (Belhoste, 2014). In addition to recording Lagrange's breakthroughs, these writings heavily influenced nineteenth century mathematicians, thus laying the foundation for even more mathematical progress in the future. If the French Revolution had not pushed Lagrange back into teaching and writing, his innovations in the fields of differential calculus, infinitesimals, and number theory may have been lost (Belhoste, 2014).

The French Revolution also rejected the systems and traditions of the overthrown monarchy. Again inspired by the ideals of the enlightenment, the new French government decided to abolish the previous measurement system and create a new universal one based on the natural world instead of local traditions. The French government enlisted Lagrange and others to create this new measurement system, and this endeavour was his focus for several years in the 1790s. Not only was this significant in Lagrange's life, but it remains essential in our lives today. The system he and his colleagues produced was the metric system, the first standardized and universal measurement system, and has been widely used ever since. In this way, the French Revolution and the ideals it put forward influenced Lagrange to pursue one of his most influential and lasting achievements, the creation of the metric system (Belhoste, 2014).

Despite being threatened with arrest and execution during the Reign of Terror, Lagrange embraced and was influenced by the enlightenment ideals of the French Revolution including reason and education. From his transition into teaching and writing and his work on the metric system, it is clear that living in France during the French Revolution profoundly shaped Lagrange's life and legacy. These changes in Lagrange's life during his time in France reflect the broader restructuring of society brought on by the French Revolution.

5.4 1792-1813: After The Revolution

Lagrange helped to develop a free public teaching system throughout France (Gindikin, 2007). Lagrange played a crucial part in the development of this teaching system as he was tasked with selecting adequate teachers (Belhoste, 2014). Adequate teachers were trained with teaching from many scientific professionals and as such Lagrange began teaching future professors and teachers at the École normale (Normal School) (Belhoste, 2014). Lagrange was the Head of Mathematics at Normal, assigning Laplace to teach alongside him. His teachings with Laplace reinvigorated his desire to teach. This along with the policy requiring professors at Normal to attend lessons outside of their area of study led Lagrange to attend many of Monge's lessons as he was interested in new geometry teachings. He helped Laplace and Monge develop the Principals of Intermediate Values (Gindikin, 2007). All of the lessons at Normal were published, which helped to solidify the Normal's place in history. After only three months, Normal was shut down, but Lagrange's approach to education standards were mimicked and had a permanent impact on the newly reformed French education system (Belhoste, 2014).

Lagrange would travel from Normal to The Central school of Public Works founded by his colleague Monge. The School strived in training engineers for the French Republic war initiative. Most students couldn't follow Lagrange's lectures so they would be held once every ten weeks and were only attended by a few promising students. Monge and Lagrange would take separate approaches to their teachings at The Central School compared to the Normal, however both would push the boundaries of mathematical principles (Belhoste, 2014). Monge preferred working with algebra and geometry while Lagrange took a strictly algebraic approach. Lagrange's teaching would influence many future breakthroughs such as binomial expansion, a new proof for developing a function into a Taylor series, and differential and integral calculus on a solid basis. These mathematical theorems stood the test of time, and continue to be taught in modern universities to this day (Belhoste, 2014).

Near the end of Lagrange's life he was given credit by many people and quoted saying "what one learns well, one learns on one's own." He became very philosophical in his old age finally agreeing that although he rejected geometry and figures it is an important utility as it can help to better experience mathematics and science, which are best understood through sensual experiences rather than words (Belhoste, 2014). His final recorded words, written in a letter, reinstate his life's passion stating that he was grateful for the emperor's fortune and favor but that he would not become jealous or proud (Belhoste, 2014). It went on that his legacy although good on paper was much better to experience and that anyone seeking to truly learn cannot do so simply in a library and they must add meaningful experiences to their life (Belhoste, 2014).

6 Abu Ali Sina (980-1037)

The Father of Modern Medicine

By Kristine Lamont, Mahmoud Mousa, Rashed Hourani, and Sean Holmes

6.1 The Beginnings

Avicenna was born in the village of Afshana in 980, near the city of Bukhara, during a time period when central Asia was under Muslim rule for almost 100 years (Khan, 2006). His family was Persian by their roots, and at the time all of Uzebekistan was included in the Persian empire (Khan et al., 2020). His father, Abd Allah, was the governor of Kharmaithan, which was the administrative capital of the Samanid caliphate (Khan, 2006).

The city of Bukhara, located on the Zarafshan River, grew into an urban center from the surrounding villages. This region was known for its fertile land, making it a common route for traders travelling from Rome and Constantinople on their way through the middle east headed for China and Russia (Khan, 2006). Under the rule of the Samanid dynasty, Persian was reinstated as the official state language, and they supported Arab and Persian writers, philosophers and poets. At the time of

Avicenna's birth, the Samanids were beginning to lose power (Khan, 2006). The population at the time of his birth was changing, but still included Muslims, Jewishs, Christians, Zoroastrians, and Buddhists. Conversion to Islam at this time was slower and more resisted in some areas, but it became the largely dominant religion by means of social pressure and other incentives (Goodman, 1992).

Avicenna's education involved learning Arabic so that he could read the Qur'an. He was then educated in the sayings of Muhammad, educated in Islamic law and jurisprudence. He was further educated in poetry, literature, and grammar. Avicenna is noted for his remarkable memory, having memorized the Qur'an at an early age. His upbringing was surrounded by philosophical and religious conversations and constant learning opportunities. A resident tutor was employed following the conclusion of his religious studies to teach him science and philosophy. Exposure to various laws allowed Avicenna to learn about deductive reasoning and logic from a young age (Khan, 2006).

While learning philosophy Avicenna took an original approach, tackling the logic of genus and species in a conceptual, less conventional method. He often worked ahead of his tutor, moving on to cosmology and astronomy by reading Ptolemy's Almagest. He worked through the mathematical problems independently, relying on his tutor only to check them. Avicenna later studied the texts of Aristotle's Physics and Metaphysics (Goodman, 1992). This educational journey follows the Aristotelian curriculum that was relevant in his day. The pathway involves moving from the tool of theoretical research which is logic, onto the primary discipline of metaphysics (Adamson, 2013). It was through this diverse and dynamic upbringing that Avicenna was able to grow and advance at such an accelerated pace.

6.2 A Multi-faceted Career

Avicenna had accomplished a lot of important feats throughout his extensive career. When he was at the age of sixteen, Avicenna decided to put all his efforts into learning the art of medicine and by the age of eighteen, he was recognized as a reputed physician. Some of his many accomplishments include curing the Ruler of the Samanids, Nuh II (Sina et al., 1974). By doing so, he was granted access to an exclusively stocked royal library where he spent a lot of time researching and advancing his theories of medicine, psychology, and pharmacology to geology, physics, astronomy, chemistry, and philosophy. It was from this library that Avicenna began writing and creating summaries of his readings and completed his first three compositions (Adamson, 2013).

Over the years, it is believed that he has written over 450 publications, however, only 240 survived (Sina et al., 1974). One of his most significant books is called *Al Qanun Fi Al-Tibb*, which is an immense encyclopedia of medicine. This book is so important because it highlights the knowledge that was available from ancient and Muslim sources, in addition, it was used as an important book for future generations to come that pursued a similar career. To this day, this book has a lot of significance and helped advance the field of medicine tremendously. Another major work that was completed by Avicenna was called *The Book of Healing*, which is a scientific and philosophical encyclopedia, primarily intended to heal the soul (Sina et al., 1974). In this book, Avicenna developed his own methodology to approaching life and the soul.

While mastering astronomy, he suggested that Venus is closer to the sun than the earth. In addition, he was able to invent an instrument they could use to observe the specific coordinates of any given star. He was also the first to state that the stars were self-luminous. Avicenna wrote in a lot of different genres, however, one of his most profound innovations was the development of *summa philosophiae*, which included all parts of philosophy. He had much self-taught philosophical training, which was rewarded generously in his work which would eventually encompass most of the philosophical culture at the time. *Compendium on the Soul*, which was fully dedicated to the Samanid ruler, presented the theoretical knowledge to be acquired by the "rational soul" (the masses) to be as detailed and as precise as he classified in the philosophical curriculum. He went on to write seven more such summae in his career such as the monumental *The Cure (al-Shifā')*, which also helped advance his teachings throughout the Islamic world.

6.3 The Philosopher

One of his many accomplishments during the end of his life was comparing Eastern Philosophy with Western Philosophy, where he gathered researchers of which they disagreed on various topics. In one of his last Summa, he diverged drastically from traditional ways of presentation and introduced an allusive and suggestive style called "pointers and reminders", in which he borrowed topos of late antique Aristotelian commentarial tradition, which was used to train students by giving them hints on theories already developed for them to learn how to think critically and understand the fundamentals of such theories.

Abu Ali Sina, also commonly known by his Latin name of

Avicenna, was a Persian polymath and a historic physician from the Islamic golden age. Not only did he have a significant impact on medicine developments and findings, he was also a great advocate for his religion and beliefs. He was a devout Muslim that often merged rational philosophy with Islamic theology.

The British Orientalist, Edward G. Browne, believed that Abu Ali Sina was a much better philosopher than he was a physician. This is because Avicenna has many books and articles on Islamic philosophy subjects such as logic, ethics, and metaphysics. His goal was to reconcile rational philosophy with Islamic theology in order to prove the existence of god through science, logic, and reason. Avicenna was famous for his contributions and research in the fields of Aristotelian philosophy and medicine. It is believed that the Muslim writer, Ibn al-Muqaffa, paved the way for the Aristotelian logic for the Islamic world almost two centuries before Avicenna. Avicenna learnt Aristotle's metaphysics from a book written by the first Islamic Aristotelian philosopher, Al-Kindi, and turkish polymath, Al-Farabi. Even though these people preceded him and laid the foundation for his work, he remains by far the greatest.

Avicenna was considered a genius with an exceptional IQ. He managed to memorize the entire Muslim holy book, the Qur'an, by the age of 10. Memorizing the Qur'an is not an easy task and it is considered an honourable accomplishment. It consists of 114 surahs (chapters) and 6,236 ayats (sentences). Abu Ali Sina was of the culture of Abbasid Caliphate, which was a ruling dynasty based on the precepts of the first Muslim ummah (community) in the Islamic world. Therefore, his culture was significantly different than in the 20th century. Avicenna and his culture's ideology was centred around god, also known as theocentric, rather than anthropocentric (centred on humans), which was the Greco-Roman worlds belief.

Abu Ali Sina's viewpoint acknowledged god as the creator, the first cause, and not a parent or an offspring to anyone. Avicenna also believed that god communicated with humans indirectly through the descended divine book, the Qur'an. This book descended on the messenger, prophet Muhammad (peace be upon him), by an angel sent from God to be an advocate of Islam and to spread the holy message. Avicenna was committed to Islam and to proving the existence of god to his community through science and logic. Abu Ali Sina had plenty of books on medicine, philosophy, psychology, metaphysics, logic, and religion. One of his most significant pieces of literature was *Risalah fi Sir Al-Qadar*, which translates to *Essay on the Secret of Destiny*. This explored the reasoning and traditions in Islamic ethics.

6.4 Time in Hamadan

Throughout Avicenna's life he moved around from country to country due to the political turmoil and war that plagued the Middle East during his time. Avicenna was residing in the capital city of al-Rayy in the Jibal province under the service of al-Sayyida and her son, Majd al-Dawla. While in the capital city, Avicenna wrote one of his many works called *The Return*. When al-Sayyida died, the soldiers mutinied against her very young son and Avicenna fled the capital fearing for his life (Sina et al., 1974).

Avicenna eventually settled in Hamadan, where he was in the service of Kadhabanuyah and handled her business affairs. Hamadan's prince Shams al-Dawla developed a colic and summoned Avicenna to treat him. Avicenna successfully treated the prince and was awarded robes of honour and became a companion of Shams al-Dawla (Khan, 2006). Avicenna accompanied Shams al-Dawla as a physician, literary, and scientific advisor throughout the prince's numerous campaigns. Ibn Sina was appointed as the Vizier, a high-ranking political advisor in the Muslim world, in Hamadan, but the soldiers mutinied against him and wanted him dead. Instead, Shams al-Dawla banished Avicenna from Hamadan, but when afflicted with another colic called upon Ibn Sina to return to treat him as the Vizier once again. Avicenna wrote The Shifā' and the first book of The Qanun while he served his second term as the Vizier (Sina et al., 1974).

After the death of Shams al-Dawla, Avicenna was imprisoned in Hamadan until Ala al-Dawla seized the city. Ibn Sina then accompanied Ala al-Dawla as a similar companion. Avicenna was stricken down with colic several times throughout his companionship with Ala al-Dawla. On a campaign to retake Hamadan, Avicenna developed severe colic that drained so much of his energy that he could not walk. Once he reached Hamadan, he understood that his illness was dire and stopped treating himself (Khan, 2006). The disease eventually took its toll on Avicenna, and he died in Hamadan at the age of 58.

Since a young age Avicenna was considered an outstanding practicing physician and through his life wrote many medical texts covering a huge area of the field. The Qanun is one of his most famous works and its medical information was taught in Europe until the 17th century. Avicenna's medical knowledge influenced many students well after his death and taught about the principles of science. Sir William Osler labeled Avicenna as "the author of the most famous medical text-book ever written". Avicenna's Aristotelian approach to philosophy helped him organize texts that include a range of all human information. During the medieval period in Europe, Avicenna's philosophy was greatly incorporated into the upcoming works. Avicenna is "one of the greatest thinkers ever to write in Arabic" according to British philosopher Anthony Flew.

Avicenna was one of the greatest minds during the Islamic golden age, which sparked a resurgence of intellectualism in Europe. He is considered one of the greatest minds to ever live in the Islamic community. His importance as an Islamic figure can be seen from the conversion of his tomb into the Mausoleum of Avicenna in Hamadan. The mausoleum is a major tourist location as intellectuals and the public are still drawn to Avicenna through his legacy.

7 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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