THE WALK OF LIFE

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EDITED BY AMIR A. ALIABADI

The Walk of Life

Biographical Essays in Science and Engineering

Volume 7

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I measured the skies, now the shadows I measure. Sky-bound was the mind, earth-bound the body rests.

—Johannes Kepler

Dedication

Delgosha Nasiri Moghaddam

Preface

The essays in this volume result from the Fall 2023 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 Roger Apéry, Niels Bohr, John Maynard Smith, and Johannes Kepler. 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 Roger Apéry (1916-1994)

The Man behind Riemann's Zeta Function Evaluated at 3

By Madison Ryckman, Caleb Niro, Timothy Wang, and Seif Radwan

1.1 Introduction

Roger Apéry was born in Rouen, France on November 14, 1916, to parents Geroges and Justine. From a young age, Roger had a passion for history and mathematics and pursued a bachelor's degree in mathematics and philosophy which he received in 1933 (Apéry, 1996). Apéry provided many contributions to the scientific community, his most widely known theorem, the Apéry Theorem, proved that the Riemann zeta function (ζ) evaluated at 3, is irrational (Lipton and Regan, 2013). This outcome was a result that the renowned Leonhard Euler overlooked, and initially, there were doubts about Apéry's argument (Lipton and Regan, 2013). However, Apéry's reasoning proved to be robust, successfully resolving this enduring, unresolved problem. Living to the age of 78, Roger Apéry passed away on December 18, 1994, in Caen, France, after enduring a long battle with Parkinson's disease.

1.2 Early Life, Family and Education

After his father of Greek heritage, Georges Apéry, moved from Constantinople to France in 1903, he met Justine Van Der Cruyssen, Roger's mother, who was of Flemish orgin. During the first four years of Roger's life, the Apéry family lived in Rouen and in 1920, they moved to Lille, where Georges worked as an engineer and Justine taught piano. Roger showed a high aptitude and was thought to be an exceptionally intelligent child. He attended a school called lycée Faidherbe in Lille, and his academic prowess was evident as, by 1926, he was two grades ahead of his peers. The family relocated again in 1926 to Paris, where Roger continued his education at the lycée Ledru-Rollin. After receiving his degree in mathematics and philosophy, from 1944 onward, he presided over the scientific philosophy circle at the École Normale Supérieure (Apéry, 1996). With the guidance of Paul Dubreuil and Rene Garnier, Apéry completed his doctoral dissertation in algebraic geometry in 1947 (van der Poorten and Apéry, 1979). Apéry assumed the role of a professor at the University of Rennes and two years later, in 1949, he became a professor at the University of Caen, where he continued until his retirement (van der Poorten and Apéry, 1979). Later, he worked alongside Ferdinand Gonseth on the Dialectica journal, joined the editorial committee in 1952 and served as a director's advisor in 1966 (Apéry, 1996). In 1979, he presented an unanticipated proof demonstrating the irrationality of $\zeta(3)$, which represents the sum of the reciprocals of the cubes of positive integers (van der Poorten and Apéry, 1979).

1.3 Life Events

Roger had undergone a lot of political turmoil during his tenure as an engineer and had undergone both World War I (WWI) and World War II (WWII). His father had enlisted in the French military during World War I in 1914 to regain French citizenship due to his Greek ethnicity. For his service, he was awarded the Croix de Combattant Volontaire due to his spontaneous and voluntary enlistment. Due to influence from his father, Roger held strong political stances during his tenure as an engineer and had started developing ideologies and stood on the side of radical socialism and joined Camille Pelletan's Radical Party in April 1934. However, after the Munich Agreement of 1938, Roger had decided to cut all ties with the Radical Party after the French premier Édouard Daladier had signed onto Germany annexing Sudetenland. Roger was thrusted into another World War after being drafted in September 1939. He was promoted to sublieutenant in the 145th Artillery and sent to the Battle of Nancy. After a grueling 10-day war, Roger and his fellow French comrades were captured and became prisoners of war. He was eventually sent back to France after being diagnosed with Pleurisy in 1941. After returning, Roger had tried to continue his academic career during this restless political time-period in France due to Germany's occupation. He continued fighting for his beliefs and became director of a French resistance movement at the École Normale Supérieure called the "Front National". He had been forging identity papers at the institution and was caught by the Nazi Secret Police (Gestapo). The director of École Normale Supérieure, Georges Bruhat was punished for Roger's resistance activities and taken to the Buchenwald concentration camp where he died. His political career continued in the 1950s and he was under the political wing of the Prime Minster Pierre Mendés France. He eventually became a candidate of Pierre's legislative ticket and had supported him at every turn including the political attacks against the rivalling communist and Gaullist parties. Roger was placed in charge of the Audin committee which was an investigation put in place after a Communist activist, Maurcie Audin was arrested and never seen again. He was a respected individual in the community as he was a mathematics professor at the University of Algiers. The military reported that he had escaped, however his friends and family had caused a public uproar leading to the investigation. After more years of slowly integrating himself back into the Radical Party, he officially cut all political ties in 1969 after General de Gaulle, who had been a political figure that directly opposed Rogers views, retired. De Gaulle's colonial and militaristic approach to politics had been the main fuel for Roger's inspiration to defend the interests of France.

1.4 Achievements and Career

Roger Apéry is a very distinguished mathematician, and his work has greatly influenced the fields of algebraic geometry and number theory. Apéry was able to overcome the disruptions of WWII and produced groundbreaking research throughout his career. Roger's early work was focused on Italian algebraic geometry, in which he developed a theory of ideals in graded commutative rings without zero divisors (Apéry, 1996). Despite his mobilization during WWII Apéry kept pursuing mathematics and completed his doctoral thesis in algebraic geometry in 1947 under the guidance of Paul Dubreil and René Garnier. In the 1950s Apéry began working more in number theory, he analyzed Diophantine equations with a focus on

$$x^2 + A = p^n, \tag{1.1}$$

where A is a given positive integer and p is a prime. Roger discovered that except in the case of $p = 2$, $A = 7$, there were at most two solutions. The most notable discovery of Roger's career came in 1978 when he proved the irrationality of $\zeta(3)$, where zeta denotes the Riemann zeta function

$$\zeta(s) = \sum_{n=1}^{\infty} \frac{1}{n^s} = \frac{1}{1^s} + \frac{1}{2^s} + \frac{1}{3^s} + \dots, \tag{1.2}$$

where n is an integer and s is a complex variable. Despite his remarkable contributions to mathematics Roger never won a Fields medal, which is regarded to be the highest honour in mathematics. Despite him not winning these highly decorated awards Roger is still greatly celebrated and recognized among the mathematical community for his proof of the irrationality of $\zeta(3)$. This led to $\zeta(3)$ being named the Apéry constant.

1.5 Challenges in Life

Roger Apéry was born in France (1916) in the middle of WWI and lived through WWII (1939 –1945). Both World Wars were an essential part of his life as they significantly impacted him and embodied a huge part of his struggle as a scientist and a researcher due to his political views during the wars. Roger was drafted in September 1939 into the French army in WWII, then he was taken as a prisoner of war in 1940. He spent 1 year as a war prisoner until he was diagnosed with Pleurisy in 1941 and was sent back to France where he was hospitalized. These events put a pause on his research but also allowed him to connect with some professors from Germany when he was a prisoner via letters from the Red Cross. WWII did not only represent a struggle in the form of fighting and harsh conditions for Roger, but also shifted his focus from his mathematical research and allowed him to dive deeply into the already existing roots of his political views and beliefs.

Apart from his struggles during WWII, Roger also suffered from a difficult childhood. As the deteriorating economic crises of France caused his father to lose his engineering job and forced him to work as a custodian to support his family; then as a result, Roger grew up poor. Also, he struggled with technical and labor work as he felt inferior to his counterparts and had to rely on his intellectual abilities, which led him to mathematics and research. He also faced a language barrier at the beginning of his life being originally from Greece but born in France and only studied beginner-level German and Italian. While his mathematical success cannot be denied, he failed to balance his research and political activism with his personal life. This led to a divorce between him and his first wife (Denise Bienaimé) and mother of three children in 1971 and then another divorce from his second wife (Claudine Lamotte) in 1977. This shows the tense mental challenges that Roger had to endure during that period of his career and its devastating effect on his romantic life.

During the last years of his life, Roger's health deteriorated drastically. He survived colon cancer after a successful operation, but he was also diagnosed with an uncurable disease called Parkinson's in 1977. That disease caused a devastating downward projection in his intellectual and functional abilities, for instance, he lost the ability to write and play the piano. Also, he started losing control over his body and rarely went outside, ultimately leading to his death in 1994. It is assumed that Parkinson's disease was also responsible partially or completely for his antisocial and distracted behaviors as he was often referred to as the "absent-minded professor" by his students.

1.6 Conclusion

Roger Apéry lived a great life that was filled with many challenges as well as many significant achievements. Apéry who was born in Rouen, France in 1916 graduated at the young age of 17 with a bachelor's degree in mathematics and philosophy. The effects of WWII were felt strongly in Apéry's academic career. He participated in the French military during this conflict and was later taken as a prisoner of war. Apéry made significant contributions to mathematics in two main areas: number theory research and Italian algebraic geometry. The discovery that Apéry will always be known for was his proof that $\zeta(3)$ is irrational which the famous Leonhard Euler missed.

Apéry's personal life also faced many challenges. He was unable to properly balance his research, political involvement, and personal life which led to multiple divorces. After a long battle with Parkison's disease, Roger Apéry passed away at age of 78 in Caen, France. Roger overcame many obstacles in his life and his legacy lives on through his namesake, the Apéry Constant, and the great research he carried out during his career which continues to greatly help modern-day mathematics.

2 Niels Bohr (1885-1962)

A Legacy of Physics, Philosophy, and Peace

By Monique Dulong, Melissa Lloyd Ibarra, Chloe Lin, and Étienne Malherbe

2.1 Beginnings

Niels Henrik David Bohr was born on October 7, 1885, in Copenhagen to Ellen and Christian Bohr. His father was a Professor of Physiology at Copenhagen University, and his mother came from a prominent family in the field of education. Niels had two siblings: an elder sister, Jenny, and a younger brother, Harald. Due to the nature of the parents, the Bohr children grew up in a house where an interest in science was a part of their everyday life. With his father being a two-time Nobel Prize nominee, the children often listened in when established scientists would work with their father, piquing their interest in the exploration of science. Niels had a strong interest in hands-on learning and physical activity from a young age. He was good at working with his hands, building things out of wood and toying with mechanical items that were needing repairs for his family. In addition, he played football frequently with his brother Harald, who went on to play for the Danish national team.

Bohr began his schooling at the Gammelholm Latin School at age seven. The Gammelholm Latin School was extremely strict, and Bohr excelled in his classes, earning the top spot in all but Danish. As the years at the Gammelholm Latin School ebbed on and Bohr began taking upper year classes, his abilities in physics were noticed. Finally, once he completed his secondary schooling, Bohr began his schooling at Copenhagen University under Professor T. N. Thiele and Professor Høffding. He initially took classes in mathematics and philosophy, and eventually began to study physics under Professor Christian Christiansen, completing his masters in 1909. His master's focused on the differing physical properties of metals. During the summer between finishing his master's and beginning his doctorate, he met Margrethe Nørlund, who would later become his wife. Bohr defended his thesis at the beginning of 1911, which expanded on the ideas he touched on in his masters: the electron theory of metals.

2.2 Physics Breakthrough

Bohr traveled to Manchester, England, in 1912 to work with physicist Ernst Rutherford who was working out a novel model of the structure of atoms. The year before, Bohr had spent some time in Cambridge, England, expanding his scientific network, including meeting prominent physicist J. J. Thompson. Thompson proposed that the atom resembled a sphere of uniform positive electrification enclosing negatively charged "corpuscles" (Petruccioli, 2006). Bohr was familiar with Thompson's "plum pudding" atomic model and had hoped to collaborate with him on electron theory. However, Thompson was not interested in the matter. Ernest Rutherford, on the other hand, welcomed

Bohr's ideas to hypothesize how atomic structure could instead consist of a densely packed charged nucleus and a number of surrounding charged electrons (Hänsch et al., 1979). According to the laws of physics understood at the time, this model was impossible because electrons would fall into the nucleus radiating all their energy. However, Bohr worked to explain how an electron could exist in a stationary state without dissipating energy using Max Planck's quantum principle and Balmer-Rydberg equations of atoms' line spectra (Hänsch et al., 1979)

$$\frac{1}{\lambda} = R_H \left(\frac{1}{m^2} - \frac{1}{n^2} \right), \tag{2.1}$$

where λ is the wavelength of the spectral line, R_H is the Rydberg constant for hydrogen ($R_H \sim 1.097 \times 10^7$ [m^{-1}]), and m and n are integers $m < n$. For the Balmer series, which corresponds to transitions where the electron ends up in the $n = 2$ energy level, m can take values of 3, 4, 5, and so on. The resulting spectral lines are in the visible part of the electromagnetic spectrum. This equation was developed independently by Johann Balmer and Johannes Rydberg in the late 19th and early 20th centuries. The Balmer-Rydberg equation helped explain the observed spectral lines in hydrogen and was later generalized by other scientists for other elements, leading to the development of the Rydberg formula. The equation was an important step in the development of quantum mechanics and the understanding of atomic structure.

Bohr found mathematical relationships between Planck's constant, electron electric charge, electron mass, and angular momentum. Re-imagining the atom with electrons following fixed circular orbits, or states, Bohr was able to explain how radiation is emitted or absorbed in the form of light when an electron moves between stationary, or quantum, states. This theory supported Rutherford's atomic model and was published in a three-part paper, now referred to as Bohr's trilogy in the Philosophical Magazine in 1913 (Petruccioli, 2006).

The Rutherford-Bohr "planetary" atomic model was received with initial skepticism, but it soon became evident that it was a sound improvement from previous models like Thompson's (Hänsch et al., 1979). Bohr's innovative use of quantum theory to explain atomic behaviour opened a door for future applications of quantum theory and theoretical physics (Petruccioli, 2006). Future pupils like Wolfgang Pauli, Erwin Schrödinger, and other notable scientists went on to improve the atomic model, but the fact that the Rutherford-Bohr model is still used to teach chemistry in the 21st century demonstrates that Bohr's contribution to science transcends time. Bohr was honored for his work on atomic structure in 1922 when he received a Nobel Prize in Physics, although he was perhaps more greatly honored by being named the Head of the Institute for Theoretical Physics of the University of Copenhagen. Founding this Institute was Bohr's initiative since he believed strongly in supporting the next generation of scientists, as well as in the crucial role of quantum theory and theoretical physics in science. Bohr continued his theoretical physics research and lecturing in light of the developing interest around quantum mechanics and radiation.

2.3 Philosophical Contributions

Philosophy and science, despite not seeming similar at a cursory glance, share a deep connection. This connection can be found in their understanding of life and the real world; the examination and positing of what makes things what they are.

In addition to Niel Bohr's scientific contributions, Bohr was responsible for major contributions to philosophy, primarily through his philosophy of quantum mechanics. Amongst key philosophers of the 20th century such as Karl Popper, Bohr's philosophical beliefs stood as a controversy due to their complicated and obscure nature (Camilleri, 2017). Contrarily, many believe it to be his work in philosophy that is Bohr's greatest contribution, primarily, his concept of complementarity (Plotnitsky, 2012). Subsequently after the discovery of many modern quantum mechanics principles such as Schrödinger's wave equation and Heisenberg's uncertainty relations, Bohr's understanding of quantum mechanics began to shift significantly (Plotnitsky, 2012). Bohr presented his preliminary understanding of complementarity during the 1927 International Conference on Physics, which in turn resulted in several debates with Albert Einstein in and around 1927 (Plotnitsky, 2012). These debates led to a finalized understanding of Bohr's complementarity concept which states that the separate conditions of separate phenomena are complementary when the phenomena do not interact with each other, and the conditions to observe the phenomena can only be applied one at a time as to not interact with the others (Wang and Busemeyer, 2015). Additionally, all measurements must be considered necessary to reach a conclusion regarding the phenomena for the results to be considered complementary (Wang and Busemeyer, 2015). Simply put, the measurements of a quantum event present equally true pieces of information through results that to an observer seemingly oppose each other. This essentially means that the measurement of an event in the presence of an observer has consequences to the results, all of which are true but not at the same time. This best applies to the investigation of light from the early 1800s to the mid-1900s: some experiments proved that light consisted of waves, and some experiments proved that light consisted of particles, while ultimately, using a continuity perspective, light existing as particles and waves can be said to both be valid interpretations, despite them contradicting each other entirely.

In turn, this connects the non-apparent nature of quantum mechanics to their real and active consequences. Despite being a physics-based concept, the complementarity concept has reached into fields outside of physics and is commonly applied to psychology and philosophy. During a talk given in 1938 by Bohr, Bohr concluded his explanation of complementarity as it relates to physics by giving an example on culture, stating: "Each culture represents a harmonious balance of traditional conventions by means of which latent potentialities of human life can unfold themselves in a way which reveals to us new aspects of its unlimited richness and variety", which is to say that judgement towards others can most often be solved by rendering an understanding of the equally worthy nature of a different belief.

Bohr's complementarity concept has significant implications today through its use in quantum mechanics, psychology, and philosophy. The concept of complementarity offers not only a greater understanding of quantum mechanics but also acts as a realistic interpretation of the problems quantum mechanics encounters (Faye, 2017). Humans, the curators and constant explorers of science, arts, math, etc. can only understand such fields from the 'human' perspective, therefore proving the great importance of Bohr's physical and philosophical contributions.

2.4 WWII and the Atomic Bomb

Since its opening in 1921, physicists from both sides of WWI worked together at Bohr's Institute for Theoretical Physics at the University of Copenhagen (Aaserud, 2020). It was a haven of theoretical research until 1933 when Adolf Hitler came into power. Since Bohr's mother was Jewish and he experienced firsthand the persecution that Jewish people were receiving, Bohr invited many Jewish colleagues from Germany and provided temporary shelter before obtaining permanent positions for them elsewhere, mostly in the United States. Bohr publicly displayed his stance on the war by stating that "all cultures were of equal value" while giving a lecture at a conference in 1938. His prior student, Werner Heisenberg, then a scientist leading the German effort of creating an atomic bomb, approached Bohr in 1941 to learn about the Allied atomic bomb plans. Bohr was surprised by his former student's actions to work with Germany but thought that building an atomic bomb was impossible before the end of the war (Aaserud, 2020).

However, by 1943 his viewpoint on the possibility of an atomic bomb had changed once he learned about the immense progress of the Allied atomic bomb efforts. He agreed to join the British, and Bohr immediately became interested in the postwar political implications of an atomic bomb. He felt the need to inform the allied Soviet Union about the existence of the atomic bomb project to develop mutual trust between nations in order to avoid a postwar nuclear arms race. Bohr saw this mission was more important than developing the bomb in the first place and set out to do it himself. He made many close connections with high-ranking officials and statesmen in Britain and the United States and worked his way up the political ladder in order to talk to Prime Minister Winston Churchill, which he did on May 16, 1944, just three weeks before D-Day (Aaserud, 2020).

The meeting did not go well for Bohr as Churchill was not interested in Bohr's ideas. Bohr then met with President Roosevelt on August 26, 1944. The President claimed to share Bohr's ideals and promised he would try to convince Churchill at their next encounter in mid-September. However, when this event occurred, Roosevelt did the exact opposite. Both political leaders agreed that the best way to deal with atomic bombs was to keep their existence secret until after the war, and Bohr should be under inspection to see that he will not leak information to Russians. Bohr's actions had the exact opposite effect that he intended for them to have. Bohr later realized that Roosevelt had never taken his ideas seriously and may had falsely agreed with him as a ploy to get him to stop nagging him. It is very difficult for one person to accomplish such a large mission of international trust and collaboration, even if that person is someone with as much reputability as Bohr.

2.5 Final Years and Legacy

After WWII, Bohr returned to Denmark to restore the Institute for Theoretical Physics, and it once again became a location for researchers to meet globally and discuss freely. In 1955, Bohr, along with many other colleagues, founded the research facility Risø. The facility was dedicated to experiments and had a modern particle accelerator that would become useful in peaceful nuclear energy research. Bohr also helped in the creation of the European Centre for Nuclear Research in Geneva in 1957. Bohr left a huge mark on the scientific community and has continued to do so after his death on November 18, 1962, at the age of 77. His scientific research has helped pave the way of many scientists today, and he has left a lasting impact on the scientific world and the way it has evolved due to his research.

Perhaps, Bohr's greatest achievement, apart from integrating quantum theory into a conceptually robust atomic model, proposing the complementarity concept, and promoting a peaceful use of nuclear technology, was encouraging, leading, and directing other scientists in their pursuit of knowledge. He inspired many great minds, like Werner Heisenberg and Wolfgang Pauli, and to this day he continues to influence the next generations of scientists in classrooms with his atomic model.

3 John Maynard Smith (1920-2004)

The Revolutionizer of Evolutionary Biology

By Lucy Castillo, Dane Freiter, Matthew Goodyear, and Callie Kellar

3.1 Synopsis

John Maynard Smith was an English biologist who lived from 1920 to 2004 (Charlesworth, 2004). His family was high standing and respected within the community. Smith had a comfortable and carefree childhood and was encouraged to pursue his academic interests. His education at Eton College, bachelor's degree in engineering from the University of Cambridge, and bachelor's degree in Zoology from the University of London provided Smith with a strong background in mathematics and the sciences (Charlesworth, 2004). His education along with his passion for biology led Smith to become a prominent figure in evolutionary biology and population genetics. Smith published multiple papers on topics such as Game Theory and the evolution of sex. During his long career, he received prestigious awards for his work and was universally admired for his academic prowess. All of those who remember him also note his friendly, social nature that was loved by all who met him (Charlesworth, 2004). Smith was said to always be open to discussing academics and captured the attention of students with his passion for biology. Smith's legacy continues to have an impact on population genetics research as the base for many modern and revolutionary works in biology that build off of those that he dedicated his life to.

3.2 Early Life, Education, and Influences

John Maynard Smith was born in 1920 to a wealthy family in England. His father was a surgeon who died when Smith was eight years old, and his mother was from a high-standing family. His parents, along with his older sister, lived in the British countryside in Exford. He had a happy childhood that included summering in Somerset with his grandparents who were heavily involved with hobby stag hunting. Smith himself also became a skilled stag hunter and fisherman. At the age of 13, he was sent to Eton College, a prestigious secondary school located in Windsor, England, where he received a general education that had a strong base in Mathematics. Smith found the environment to be pretentious and did not enjoy his time at Eton College. Smith was introduced to geneticists Fisher, Wright, Haldane, and the "founding fathers" of population genetics; and it was at Eton College that he was inspired by the works of one of the founding fathers of evolutionary biology, John Burdon Sanderson "Jack" Haldane, a British-Indian geneticist and evolutionary biologist. Haldane's *The Inequality of Man* was a collection of essays written on topics ranging from science and history to politics. The essays were unpopular within Europe as most members of high society believed the essays to be communist propaganda. Smith related to the scientific theories Haldane had proposed and began examining communist ideologies (Charlesworth, 2004).

Smith's academic capabilities became apparent when he was young, as indicated by his admittance to Eton College at such an early age. Although he did not particularly enjoy this time, it was critical for his educational development and acceptance into the engineering program at the University of Cambridge. This education proved particularly useful as World War II (WWII) broke out across Europe, during which Smith was involved in aircraft design for the British military. Although he had initially planned to serve in the armed forces, he was rejected due to his poor eyesight. He viewed this rejection in a positive light later in life, acknowledging that he may never have made such significant scientific contributions had he been a casualty of the largest historical conflict to date. It is somewhat unclear if the war itself influenced his choices but following its end, Smith decided to undergo a drastic academic switch to the biological sciences (Charlesworth, 2004).

In 1938 Smith accompanied his uncle to Berlin, Germany, and he was exposed to the fascist politics of Germany under Hitler's Nazi regime. His experience with his classist peers and later experience in Berlin drew Smith to communism and left-leaning politics. Smith was an active member of the communist party of Cambridge, and he held on to these beliefs through his young adult life. In later years Smith saw flaws in Marxist Communism and openly criticized the party. He was humble and kind to everyone and believed in politics which reflected that. Even as he grew into a brilliant biologist, he remained modest and approachable. Later in his career, he was known for drinking beer at lunch and spending the rest of the afternoon discussing ideas with young students and colleagues (Charlesworth, 2004).

While studying zoology (specifically fruit fly genetics) at the University College London (UCL), Smith became acquainted with Haldane and studied under him. Haldane is considered one of the primary contributors to Neo-Darwinist Theory, which affected Smith academically, but also in a more personal manner, as it influenced his religious and political affiliations. Smith was very drawn in by Haldane's work, despite its seemingly controversial nature among the general scientific community (Charlesworth, 2004).

Haldane's work motivated Smith's pursuits while also facilitating his full transition to atheism, which he had started as a teenager. This was particularly interesting as many in his field at the time did not consider religious belief and evolutionary belief to be mutually exclusive. It was also during and shortly after this period that his left-leaning tendencies were most apparent. This is likely attributed to his ongoing exposure to classist tendencies and the fact that certain communist-related tragedies had not yet unfolded. He continued as a lecturer at UCL following his graduation, where he met his wife Sheila. Despite his academically gifted mind, he decided not to pursue a doctorate, as he felt it was not significant in the grand scheme of his pursuits (Charlesworth, 2004).

While Smith enjoyed a relatively comfortable early life and career, he faced adversity in gaining respect and acceptance for his ideas among his peers. Haldane and Fisher were academic rivals with two different schools of genetics. The major disagreement between Haldane and Fisher was related to the genetics of dominance (Edwards, 2017). Since Smith was associated with the genetic school of Haldane, he did not get along with Fisher. Fisher went as far as to make a show of standing, putting on his coat, and then leaving shortly after a young

Smith began giving a lecture to the United Kingdom Genetical Society (Charlesworth, 2004).

3.3 Career Endeavours

Smith revolutionized evolutionary biology and genetics throughout his long career. In 1958, he published his first work, The *Theory of Evolution*. This publication served as an introductory text to evolutionary biology and amassed great success. Even at a young age he was often described as an outstanding communicator of science and credited with stimulating new interest in evolutionary biology and ecology through this publication and *Models in Ecology*, published in 1968 (Charlesworth, 2004).

Smith went on from UCL to become one of the founders of the University of Sussex in 1962 where he performed some of his most influential work in applying certain principles of Game Theory to evolutionary progression. Although the first to propose such comparisons was Richard Lewontin in the early 1960s, Smith is viewed as the most significant contributor to the theory, publishing his first papers focused on the topic in 1972 and 1974 (Michod, 2005). By incorporating the musings of American geneticist George R. Price, Smith identified and solidified a concept known as the Evolutionarily Stable Strategy (ESS). The general premise is that certain animal behaviours are deemed "evolutionarily stable", specifically those which are adapted by much of a given population and allowed to proceed undisturbed by additional environmental factors and intra-population interactions. This research was summarized in *Evolution and the Theory of Games*, which was published in 1982 amid his early work on other topics (Michod, 2005).

Smith also researched the fascinating concept of the "twofold cost of sex" when comparing sexual and asexual populations. One key drawback is that parents lose genetic representation in their offspring, resulting in a potentially less fit species population. In contrast, asexual reproduction yields offspring that are genetic duplicates of the parent, causing a doubling of asexual reproduction in the species population with each generation. His focus was addressing the question of why species persist in sexual reproduction despite the advantages of abandoning sex. He explored two theories to address this question. The first suggests that sex plays a crucial role in DNA repair, while the second hypothesized that sexual populations excel in avoiding harmful mutations by producing offspring without detrimental mutations present in their parents.

Smith documented his comprehensive findings in his publication, *The Evolution of Sex* (1978), providing a valuable contribution to our understanding of the complex dynamics surrounding sexual reproduction and evolutionary implications, winning him the Balzan Prize for Genetics and Evolution in 1991. In his genetic research, Smith pioneered the use of the fruit fly Drosophila as a model organism for studying the biology of aging; a practice that continues to be embraced by evolutionary biologists today (Michod, 2005).

Smith's research interests were centered on the realm of animal behaviour. In his last work, he collaborated with his colleague David Harper to analyze behavioural patterns and mating consequences of inbreeding. Having developed extensive experience using Drosophila in his scientific research, he studied the male species. His findings led him to discern that sexual selection by the female has been overlooked by his colleagues. In *Animal Signals* (2003), he defends that the impact of sexual selection by the female has evolutionary significance and plays a pivotal role in yielding offspring with robust fitness traits

(Charlesworth, 2004).

3.4 Awards and Legacy

For his remarkable contributions to the field, Smith garnered widespread recognition within the scientific community, earning numerous prestigious prizes and awards. Notably, in 1999, he was honoured with the Crafoord Prize for his fundamental contribution to the conceptual development of evolutionary biology. The accolades continued in 2001, when he received the Kyoto Prize in Basic Sciences, for applying game theory to biology. His innovative concept, the Evolutionarily Stable Strategy (ESS), has maintained its relevance and serves as an effective tool in various fields including economics, business sciences, and politics. Towards the end of his career, Smith was considered for knighthood but declined the offer. This speaks to his unwavering commitment to the pursuit of knowledge over the allure of titles and honours (Michod, 2005).

Ultimately, Smith's contributions to the biological sciences provide a critical link between the early minds of evolutionary and reproductive theory and current technologically aided analyses. His changing political and religious affiliations are indicative of a person who abides by logic and available information, as many scientific minds are. Conversely, his reportedly easy-going nature and willingness to engage students show his humble nature and devotion to the furtherment of education. His general indifference to pursuing a Ph.D. further showcases his desire to pursue meaningful scientific contributions rather than superfluous titles. He passed away sitting in a chair in his study, surrounded by books, a final indication of a man with a deep passion for the scientific world. Smith's work will certainly be acknowledged for many years to come (Charlesworth, 2004).

4 Johannes Kepler (1571-1630)

The Revolutionary Astronomer

By James Lovett, Alanna Mills, Maegan Segne, and Jeffrey Obempong

4.1 Early Life and Education

Johannes Kepler was born on December 27, 1571, in Weil der Stadt, Germany. At the time, the heliocentric model was not widely accepted, Tycho Brahe was a young astronomer at the age of 25, and both Galileo and Shakespeare were just seven years old (Love, 2009).

With a mother who was loud and unpleasant and a father who was described as an "immoral, rough, and quarrelsome soldier," Kepler had a difficult early life. He faced challenges with his health, overcoming smallpox at the age of three, and his mercenary father abandoned the family when he was a teenager, never to return.

Despite these challenges, Kepler experienced happy moments in his early life. His mother took him outdoors in 1577 to see a brilliant comet, which was coincidentally the same comet that Tycho Brahe had seen in Denmark, and which refuted the Aristotelian theory that it was located beyond the Moon.

Kepler's academic career started at the Protestant Seminary at Adelberg, where he was well-versed in the humanities, Latin, and Greek. At the Grammar School in Maulbronn, where he pursued further education, he was exposed to courses like astronomy and mathematics. This was a particularly valuable time for Kepler's intellectual development because it introduced him to the groundbreaking Copernican model of the solar system.

Kepler was a gifted student who gained admission to the esteemed Tubingen University in 1589 to study philosophy and theology in preparation for a career as a Lutheran clergyman. He was first introduced to mathematics and astronomy by one of the leading astronomers of the day, Professor Michael Maestlin in Tubingen, who was a proponent of the Copernican theory. This was a time where many Protestants, like Martin Luther, opposed Copernicus because they thought it went against what the Bible said. Nonetheless, Maestlin acknowledged the Copernican system's capacity for explanation and taught both Ptolemaic System and Copernican Systems.

Against the wishes of his family and his protestant upbringing, Kepler's burgeoning interest for astronomy eventually gained precedence and became the focus of his academic endeavors. Near the end of Kepler's time at the university he was offered a position as teacher of mathematics and astronomy in Graz. In 1954, at age 22, he accepted the position, ending his time at the university.

4.2 Kepler's Beliefs, Social World, and Early Work

Kepler occasionally stated that Divine Providence guided him to the study of the stars, despite his strong conviction that his calling was religious. He immediately comprehended Copernicus' fundamental principles and was instructed in its complicated intricacies by Maestlin, a mathematics professor at the University of Tubingen. Kepler intuitively realized that Copernicus had discovered an account of the universe that bore the imprint of divine planning. Kepler made it his duty to carefully demonstrate what Copernicus had only guessed to be true. And he did so using a religious and philosophical discourse.

Kepler saw nature as a book in which the divine design was recorded, and he saw his ideas embodied in nature. One of his most cherished concepts - the notion of the Christian Trinity as depicted by a geometric sphere and, thus, the visible, created world - was a tangible reflection of this heavenly mystery. One of Kepler's favourite Bible verses was John (1:14), which stated, "And the Word became flesh and lived among us." This meant that the divine archetypes were actually made visible as geometric shapes (straight and curved) that formed the spatial arrangement of evident corporeal creatures, according to Kepler. Kepler also believed that God was a dynamic and creative person whose existence in the world was symbolized by the Sun's body as the source of a dynamic force that moved the planets constantly. The natural world acted as a mirror, exactly reflecting and embodying these heavenly concepts.

Mysterium Cosmographicum (*The Cosmographic Mystery* (1596)), Kepler's first major astronomical book, was the first published defense of the Copernican system. The ideas within his first work would be what Kepler would pursue for the rest of his life. In 1594, Kepler was appointed as a mathematics professor at the Protestant Seminary in Graz, Austria, as well as the district mathematician and calendar maker. It was here in which Kepler claimed to have an epiphany; while illustrating Saturn and Jupiter's annual conjunction in the zodiac, he discovered that regular polygons bound one inscribed and one circumscribed circle at specific ratios, which he reasoned could be the geometrical basis of the world. Kepler integrated astronomy into natural philosophy in an unprecedented fashion, providing unique contributions to astronomy as well as all of its auxiliary sciences in the process.

4.3 Laws of Planetary Motion

Kepler's Laws of Planetary Motion are laws that describe the motions of the planets in the solar system in astronomy and classical physics. Kepler used observations from the 16th-century Danish astronomer Tycho Brahe to publish his first two laws in 1609 and a third rule nearly a decade later, in 1618. Kepler himself never numbered or separated these rules from his previous discoveries, however, the three laws can be stated as follows:

1. All planets move in elliptical orbits around the Sun, with the Sun as one of the foci,

2. A radius vector connecting any planet to the Sun sweeps out equal areas over similar time periods, and,

3. The squares of the planets' sidereal periods (of revolution) are proportionate to the cubes of their mean distances from the Sun.

Kepler saw these Laws as celestial harmonies reflecting God's plan for the universe. Nicolaus Copernicus' Sun-centered system was transformed into a dynamic world by Kepler's findings, with the Sun actively pushing the planets about in noncircular orbits. These principles have scientific significance since Kepler's concept of physical astronomy generated a fresh issue for other 17th century world-system designers, the most famous of whom was Newton.

4.4 Kepler's Science of Optics

Johannes Kepler made significant contributions to the field of optics through two seminal works: *Ad Vitellionem paralipomena (APO)* and *Dioptrice (DI)*. These contributions were influenced by the publication of Galileo's *Sidereal Messenger* in 1610. In his *Conversation with the Sidereal Messenger* (*Dissertatio cum Nuncio Sidereo* ... Galileo Galilei), Kepler supported Galileo's findings and emphasized the need to explain the underlying causes of observed optical phenomena, particularly in the context of astronomical optics.

Kepler's investigations in optics were motivated by questions related to eclipses, the apparent size of the Moon, and atmospheric refraction. He also explored the theory of the camera obscura and recorded its general principles. Additionally, he focused on the theory of the telescope and invented the refracting astronomical telescope, known as the Keplerian telescope, which was an improvement over the Galilean telescope.

In his work, Kepler expanded his research program to encompass mathematics as well as anatomy, discussing conic sections and the process of vision (Crombie, 1991; Lindberg, 1976b). In Chapter 1 of *APO*, titled "On the Nature of Light," Kepler presented 38 propositions related to light's properties. He asserted that light flows from every point of a body's surface no matter, weight, or resistance, and moves in an instant rather than over time. Light is propagated by straight lines (rays) and is a two-dimensional entity that tends to expand into a curved surface.

The extent to which Kepler's approach to optics can be characterized as mechanistic is a subject of debate among scholars (Crombie, 1967, 1991). Some argue that Kepler's work demonstrates a strong commitment to the mechanical physics of light, especially in his use of the camera obscura model and the concept of motion. Others, however, suggest that Kepler viewed light as having an active and constructive role in the universe, which is not in opposition to his mechanistic explanations but indicates a broader perspective on light's functions in various fields of science (Lindberg, 1976a).

The debate over Kepler's place in the history of optics revolves around whether his ideas represent continuity with tradition or a rupture from it. Both positions have well-grounded arguments, with some highlighting the mechanical aspects of Kepler's work and others emphasizing his view of light as an active and constructive force in the universe.

4.5 The Passage of Stars

Using Tyco Brahe's (1546-1601) vast catalog of star positions, Kepler was able to prepare and print the *Rudolphine Tables*. The book was composed of mathematically complex ideas paired with tables. The tables predicted the location of any planet thousands of years into the past or future with greater accuracy than Copernicus or Ptolemy were able to achieve (Voelkl, 1999).

The tables, named for his Hapsburg emperor patron Rudolph the II, took 25 years to complete.

One of the most impressive discoveries resulting from the preparation of the Rudolphine Tables was that Mercury would transit across the surface of the Sun on November 7th, 1631. This event would be observed for the first time in human history using the recently invented telescope (1608) and a screen for projection (Voelkl, 1999). Devastatingly, Johannes Kepler would not live to see the transit of mercury. In one of his many trips to Regensburg, he caught a cold which worsened with a high fever and shortly after passed away.

He would be buried at the Saint Peter's Protestant cemetery. The churchyard and Kepler's grave were subsequently destroyed by the Thirty Years War between the Protestants and Roman Catholics of Germany. His epitaph, which he authored himself, is said to have been read as follows (Love, 2009).

"I measured the skies, now the shadows I measure. Sky-bound was the mind, earth-bound the body rests."

During his life, only a few astronomers understood the impact of his work. Today, his laws of planetary motion remain fundamental cornerstones and he is recognized as a star in his field.

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

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