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Biographical Paper
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René Descartes

René Descartes is called the father of modern philosophy and he was one of the most prominent mathematicians of the Scientific Revolution of the 17^{th} century. His major contributions span the fields of philosophy, mathematics, physics, and physiology. Much of what we understand today in natural philosophy and analytic geometry is based on the original ideas of Descartes during his relatively short lifetime.

René Descartes was born March 31, 1596 in LaHaye, France to Joachim Descartes and Jeanne Brochard, a legal family to the crown. He was their third surviving child, along with his older brother, Pierre and his older sister, Jeanne. The Descartes family was originally from the town of Châtellerault in the Poitou region of France, where many of the family served as tax collectors and lawyers to the royal court. During his childhood, Descartes did not have a close relationship with his father, who was appointed to the parliament in Rennes, and therefore spent three to six months of the year away from home in the Brittany region of France. Descartes' mother and his two siblings moved from Châtellerault to stay with her mother, Jeanne Sain, in the small town of LaHaye in 1596, and this is where René was born. He was baptized into the Catholic Church on April 3, 1596 and he remained pious to the Catholic faith throughout his life. Fourteen months after his birth, his mother died and he was left in the care of his grandmother Sain until her death in 1609 or 1610. His father had remarried and moved permanently to Rennes in 1600, and so after Jeanne Sain's death, René went from LaHaye to live with his paternal grandmother Claude Ferrand in Châtellerault [3].

In the late 1500s and the early 1600s, society was divided between the Catholic Church, who still had immense power, and the Protestantism of the Reform. The Jesuits of the Counterreformation were expelled from France in 1595, and again in 1763, but in between these times, played a significant role in the education, religion, and politics of France during Henry IV's reign. Supported by the king, the Jesuits founded the College at La Flèche in 1604. Descartes attended La Flèche from the age of eleven until he was nineteen. Many sources speculate that his late start in formal schooling was because he was a very sickly child and was not accustomed to early rising in the mornings. At La Flèche, the curriculum consisted of six years of preparatory studies, including the study of Greek and Latin, followed by humanities and rhetoric; then three years of philosophy, based on the traditions of Aristotle and the ancient Greeks; and a final four years of theology, which became optional for Catholic students who chose to complete all thirteen years of schooling. Descartes completed the first nine years, and then earned a degree in law from the University of Poitiers. Then, in 1618, he left France to join the army of Prince of Orange in Holland, where he met Isaac Beekman, who introduced him to the mathematics he later chose to study in his career. After a short time in the army of the Duke of Bavaria in the Thirty Years War, he chose to pursue his education elsewhere through travel, including to the United Provinces (today the Netherlands), Denmark, Germany, and Italy. It was during this time that he had his famous three dreams that gave direction to the rest of his life and his thoughts on a unitary universal science. Later in 1628, he emigrated permanently to the United Provinces, living mostly in Amsterdam, Leiden, Deventer, and Egmond [3; 8].

Descartes spent the rest of his life in different parts of the United Provinces, mostly in northern Holland, with several trips back to France. He always attempted to keep his address secret so as not to be disturbed. He chose to lead a life in seclusion because he believed it was necessary for his studies. However, he did have a few people he remained close to throughout his life. These included Helena Jansdr vander Strom, a servant at one of the houses in which he stayed during his time in the United Provinces. On July 9, 1635, Helena gave birth to Descartes' daughter, Francine, in Deventer. Unfortunately, at the age of five, Francine caught scarlet fever and died in 1640 [3].

Another person whom Descartes remained in constant contact with was Mersenne, a Minim friar from Paris. He continuously exchanged letters with Mersenne discussing his ideas and projects and Mersenne was his link to the rest of the intellectual community. Mersenne had a great interest in the sciences, especially mathematics, and he served as the coordinator between many different European scholars during this time, including Descartes, Roberval, Beekman, Fermat, and Pascal. He and Descartes became close friends [16]. In addition to corresponding with and collaborating with other scholars of the time, Descartes also tutored Princess Elizabeth of Bohemia, who had taken an interest in his theories on metaphysics, and Queen Christina of Sweden, who studied his *Les Passions de l'âme* and *Principia philosophiae*. He was later issued an official invitation from Queen Christina to join her at court in order to give her more detailed instruction. Descartes accepted the invitation and traveled to Sweden in 1649. Several months after arriving, he caught a flu-like infection that consumed his already weak state of health. He suffered over a week of high fever and finally died February 11, 1650 [3].

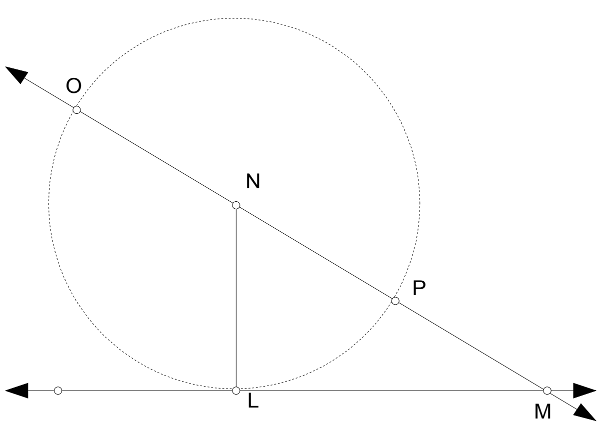
During his life, René Descartes worked on many essays and projects. Most of the time, he was busy editing, revising, and beginning new projects simultaneously. Some of his works were published during his lifetime, earning him recognition among his contemporaries, while many others were published after his death for different reasons. His work in any field usually surrounded the core of his philosophy and belief system. His very first work was entitled *Compendium Musicae* in 1618, but was not published until after his death in 1650. This work discussed music as it related to the interconnectedness of all branches of knowledge. He first set out what he called his "method" in *Regulae ad directionem ingenii*, which was left unfinished in 1628 and published posthumously in 1684. Descartes' method consisted of the manner in which anyone could seek and find any true knowledge that is possible for a human being to discover. His *Discours de la méthode*, *les Météores*, *la Dioptrique*, and *la Géométrie*, all published in one volume in 1637, were examples of applying his method in different areas. Four years later, in 1641, he published *Objections and Replies* with his *Meditationes de prima philosophia*. These works discussed how mind and matter could interact, a controversy that still surrounds his philosophy today. His *Principia philosophiae* was published in 1644 and in 1649, *Les Passions de l'âme* was published, which was designed to replace Aristotle's similar theses. Descartes' other major philosophical works *Le Monde, ou Traité de la Lumière*, along with *L'Homme*, were completed by 1633, but were not published until 1664. Following Galileo's condemnation by the Roman Catholic Church in 1633, Descartes did not publish *Le Monde* because it involved some of Galileo's ideas regarding the universe and he did not wish his work to be misread or misunderstood, even though much of his written work and correspondence makes his Catholic piety well known [4; 3].

René Descartes is most celebrated for his contribution to philosophy. He changed the face of what was understood of the field for the centuries preceding his time. He was greatly influenced by the Renaissance and the scientific illumination of the 16th century. He was well read in the works of Galileo, Torricelli, and also the ancient Greek philosophers. But although his studies gave him a strong foundation from where to start, he created an original philosophical method on his own. He is called the father of modern philosophy because he broke away from the Scholastic philosophy of Aristotle and Saint Thomas Aquinas. Descartes divided reality into mind, which consists of thinking, and matter, which is extension in three dimensions. He believed that ideas of God, mind, and matter are innate and not a result of experience. The center of his rational philosophy consisted of two principle concerns: "1) whether a form of human knowledge that is immune to all skepticism is possible, and 2) whether one can make sense of the nature of mind and its relationship to matter" [2]. He questioned the difference between the way we perceive things and the way in which things are in reality. His advice was to doubt everything until one could find an idea that is "indubitable, clear, and distinct" [2]. He believed he had found at least one such idea, which is most commonly summed up in the phrase: "Cogito, ergo sum," or "I think, therefore I am."

Descartes' philosophical studies and his application of the method in search of truths led him to the study of many other fields as well. One of his largest accomplishments was in the field of mathematics. Through his method, he believed one could search out truths on their own or could find new truths by combining already known information. The most significant example of this is his combination of algebra and geometry. The result was the founding of the field of analytic geometry with *la Géométrie* in 1637. Descartes is considered the founding father of analytic geometry along with Pierre de Fermat, who achieved the same discovery independently in his *Introduction to Plane and Solid Loci* in the same year. The two mathematicians' approaches differed in that Fermat dealt with "the relationship between algebra and geometry through the study of loci", and Descartes demonstrated "this relationship through the geometric construction of solutions to algebraic equations" [13, p.437]. Given an equation, Fermat would come up with a geometric curve to represent the equation. Descartes did the opposite, and would come up with an equation to represent a given curve. This approach allowed Descartes to study more complex equations than Fermat, which led to the analysis of polynomial equations of higher degree. These approaches followed in the tradition of Islamic mathematicians al-Khayyāmī and Sharaf al-Dīn al-Ṭūsī. The critical difference is that both Fermat and Descartes took it one step further by using coordinates to relate the two mathematics. Descartes' work was the first stage in the development of analytic geometry, but was limited compared to what we know today because he excluded any curves that did not have points that could be constructed algebraically to an exact measure. This included what we now call transcendental curves [13, p.436-442; 11].

The following are two examples of the problems that Descartes solved in his *la Géométrie*. In this work, we see his use of a consistent notation for mathematical equations. Descartes had studied the works of François Viète, who introduced the first consistent set of letters used as symbols to represent the mathematical quantities. However, his form was still primitive and similar to the ancient Greeks' method of explaining calculations. The symbolization of algebra took form when Descartes first introduced in *la Géométrie* our current practice of representing known quantities with the beginning letters of the alphabet (*a*, *b, c*...) and unknown quantities with letters at the end (*x*, *y*, *z*...). He was also the first to use modern exponential notation consistently [13, p.370, p.438; 14].

In *Livre premier* of *la Géométrie*, to construct the solution of the quadratic equation $z^2 = az + b^2$, Descartes constructs a right triangle NLM, with one side, LM, equal to the known quantity of *b* (the square root of b^2), and the other side, LN, equal to half the known quantity *a*, $\frac{1}{2} a$. Then extending the hypotenuse, MN, to a point O so that NO is equal to NL, the line OM is equal to the required value of the unknown *z*. He expresses this with the equation: $z = \frac{1}{2} a + \sqrt{(\frac{1}{4} a^2 + b^2)}$. See Figure 1 below.



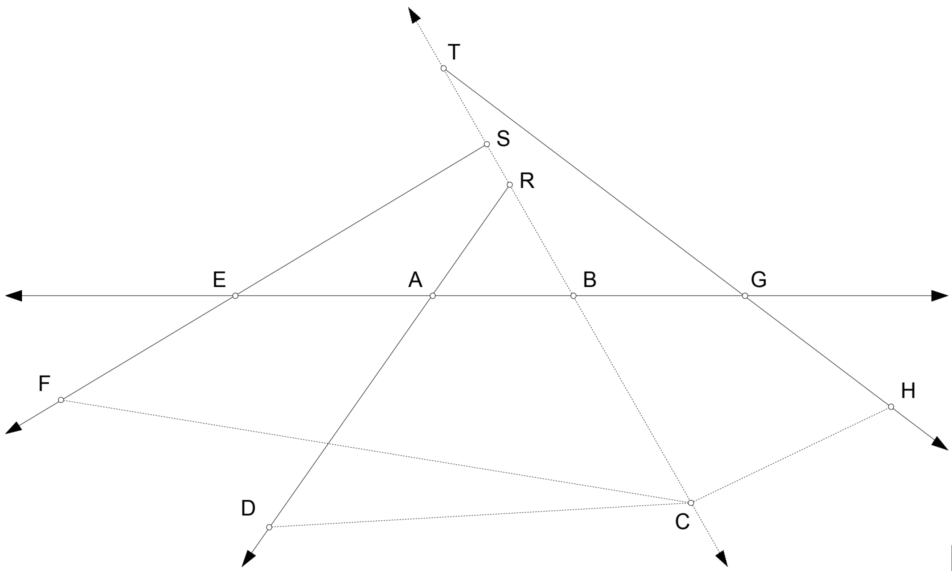
[*la Géométrie*, p.302]

Toward the end of *Livre premier*, Descartes offers a detailed discussion of Apollonius' problem of the four-line locus. The problem presents "finding of points from which lines drawn to four given lines at given angles satisfy the condition that the product of two of the line lengths bears a given ratio to the product of the other two" [13, p.438]. Descartes simplifies the problem by referring to all lines as two principle ones, labeled x and y. He sets x as the length of AB along the given line EG and sets y as the length of segment BC along the line BC, where C is one of the points satisfying the problem. Then the lengths of the required line segments, CB, CH, CF, and CD (drawn to the given lines EG, TH, FS, and DR, respectively), can be expressed as a linear function of x and y [13, p.438]. By applying algebraic representation to this geometric problem, Descartes discovered a way to represent the solutions in a general form. In *la Géométrie*, he states:

> If the question be proposed for only three, four, or five lines, the requires points can be found by elementary geometry... (and) the required points lie not only all on one of the conic sections but sometimes on the circumference of a circle or even on a straight line. When there are five, six, seven, or eight lines, the required points lie on a curve of degree next higher than the conic sections... If there are nine, ten, eleven, or twelve lines, the required curve is only one degree higher than the preceding,... and so on to infinity [p.308].
>
> Assigning a value to y, we have $x^2 = \pm ax \pm b^2$, and therefore x can be found with a ruler and compasses... If we then take successively an infinite number of different values for the line y, we should obtain an infinite number of values for

the line *x*, and therefore an infinity of different points, such as C, by means of which the required curve could be drawn [p.313].

Figure 2.



[*la Géométrie*, p.311]

In his *Livre troisiesme* of *la Géométrie*, Descartes discusses equation solving as it relates to the degree of an equation. He holds that every equation can have as many roots as the number of dimensions of the unknown quantity in the equation. He shows how equations are built up from their solutions and states the result today known as Descartes' Rule of Signs: "An equation can have as many true [positive] roots as it contains changes of sign, from + to – or from – to +; and as many false [negative] roots as the number of times two + signs or two – signs are found in succession" [13, p.448]. This Rule of Signs is an integral part of the curriculum of high school algebra today.

La Géométrie also showed the basics of one of the most fundamental founding ideas of calculus. Descartes devised a method of drawing a normal to a curve at any point, from which one could easily determine the tangent. His idea for the normal came from his realization that the radius of a circle is always normal to the circumference. And so the radius of a circle tangent to a given curve at the given point will be normal to that curve as well. His construction of this solution relied on the fact that two intersection points of a circle with the curve near the given point will become one if the circle is indeed tangent [13, p.472].

The results of *la Géométrie* influenced Maclaurin's work on the solving of polynomial equations and provided the basis of Newton and Leibniz's calculus, which made possible all the subsequent mathematics developed thereafter. He also applied math to nature with his study of optics and the geometrization of nature and how we perceive shape and distance. Although the impact of Descartes' discoveries in mathematics has been immense, one must realize that *la Géométrie* was written to demonstrate the application of his philosophical method of correct reasoning to the field of geometry. It was written as part of his larger goal of devising a superior philosophy "to help one to attain a tranquillity grounded in an intellectual mastery in making all the choices of life" [12, p.15]. He believed that natural philosophy was the only essential study in life, that his progress in the different sciences followed from his method in philosophy, and that anyone who chose to follow Cartesian philosophy could achieve the same knowledge [12; 13; 14; 15]. Philosophy played a significant role in all the other fields of science where Descartes left his mark, including his accomplishments in physics and physiology.

His most important contributions to physics were in the fields of optics and mechanics. In *la Dioptrique*, Descartes proposed his theory of lenses through four "ovals" as solutions to a generalized form of the anaclastic problem. He made advances in the study of reflection and refraction based on his theory of light and system of cosmology. Descartes described light as a "tendency to motion," rather than actual motion as we normally perceive it, which transmits impulses to us from the objects it meets, which allows us to see. This is similar to the way a blind man's cane allows him to "see." In the second half of *la Dioptrique*, he details the analysis of the human eye and the way in which we see the colors of the rainbow. He related what we see to the speed in which light passes through and the angle of the earth compared to the sun. He succeeded in providing an accurate account of refraction through a prism to produce a rainbow [14, p.58-60].

In mechanics, his most impressive discovery regards what we now call the law of inertia. He followed in Galileo's steps and supported the idea that motion is a natural state and that an object will remain in motion unless something acts upon it. He believed that motion was caused by collision of particles he called "corpuscles." And he stated that in the absence of these collisions, an object at rest remains at rest. This is clearly a description of inertial motion. Descartes' principle contribution to the idea of inertia was to state that an object's motion continues in a straight line. This rejected the idea, shared by both Ptolemy and Copernicus, that self-sustaining circular motion is possible. This was an extremely significant discovery for understanding the motion of all objects and the forces that act upon them, including the motion of our solar system [9, p.80-81].

Based on his theories of inertia and conservation of energy, Descartes devised seven laws of impact. Unfortunately, only the first of these seven laws was explained correctly: namely, the idea of two equal bodies approaching each other at equal speeds. In addition, in a letter of 1637 to a fellow scholar of the time, Huygens, he provided an analysis of the five simple machines, where he deduces that the force required to lift *a* pounds vertically through *b* feet will also lift *na* pounds *b/n* feet [14, p.58-60].

Descartes also studied in depth concepts of physiology, which he considered an integral part of his philosophy. Important ideas on animal function can be found in *Regulae* (1628), *Discours de la Méthode* (1637), *Principia philosophiae* (1644), and *Les Passion de l'âme* (1649). But many of his ideas on inanimate bodies and the nature of man were contained in his *Traité de lumière* and *l'Homme*, which he suppressed from publication following the condemnation of Galileo in 1633. His works on physiology were explained in terms of mathematics, matter, configuration, and motion. He stated that all animal and subrational human movements are controlled solely by unconscious mechanisms. He gave an account of digestion and blood circulation throughout our bodies as transference through a sieve-like function. He describes nerves as hollow tubes which transmit messages through "animal spirits," which our soul reads and delivers through the other nerves. From here he related every bodily function, and even human emotion and passion to the different motions and speeds of the spirits through our bodies. In *De la formation du foetus*, published posthumously in 1664, he gives a mechanical account of reproduction generation. His physiological ideas greatly influenced the philosophies of many scholars, including Spinoza, Leibniz, Plempius at Louvain, and Regius at Utrecht. Descartes was solely responsible for the 17th century mechanization of physiological conceptions, creating strong followers in the scientists Thomas Bartholin and Nicholas Steno after his death [1, p.61-65].

Following René Descartes' death in Stockholm, he was buried in an obscure children's cemetery near a hospital. He faced much criticism from both the Catholic Church and Protestant theologians throughout his life. Although he advocated strongly the Catholic religion, asserted even by Queen Christina of Lutheran Sweden, he faced much discrimination based on his works, especially those involving his metaphysics and the immortality of the soul. Although he never outright rejected any ideas of the Church and remained pious even on his deathbed, many still believed he was secretly atheist and that his work undermined the teachings of the Church. In fact, in 1663, the Catholic Church banned several of his works in the Index of Forbidden Books. The controversy that surrounded his life's work is reflected in the controversy that surrounded his burial [3].

Despite criticism and conflicted public opinion on the matter, after sixteen years in his grave in Sweden, his body was finally exhumed and transferred back to Paris. His philosophical supporters and friends in France wished for him to be recognized as a great philosopher in his home country. He was buried in the Church of St. Geneviève until 1792, when the church fell into disuse following the French Revolution. In 1793, the National Convention decided that his remains should be honored with a burial in the Pantheon, but this never actually took place. Over the next twenty-six years, several burial locations were suggested and on February 26, 1819, he was finally buried for the last time in the church of a former Benedictine monastery of Saint-Germain-des-Prés in Paris [3, p.408-412]. His final burial place was peaceful but did not do justice to the honor and respect he has earned in modern times. Today we recognize René Descartes for his many outstanding achievements and praise him as one of the most significant philosophers and mathematicians in history.

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