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Leonardo da Vinci: Pilot of Science

Leonardo da Vinci was ***l'uomo universale***, the infinitely versatile "universal" man. He strove to master the diverse arts and sciences of the world like many others during the Renaissance. Leonardo examined everything, ranging from mechanics to anatomy to fluid dynamics to mathematics. Such research had many applications in Leonardo's life: medicine, painting, sculpture, and his pursuit of human flight. Of these applications, Leonardo may have been fondest of flight. His fascination with human flight pushed towards mania; his efforts spanned at least 40 years of his life. The complexities involved in such a feat led Leonardo down a long, meandering path of scientific investigation. Despite repeated failures, Leonardo persevered. His curious mind mandated continuation of his extensive project. His goal lay more in the process than the result. When Leonardo passed, he had never achieved his dream—he had done something much greater. Leonardo's widespread research had set the foundation for much of modern science. In pursuing his obsession of human flight, Leonardo established himself as a pioneer in contemporary science (Capra 124).

Leonardo's interest in flight initially led him to study anatomy. His notebooks contain countless sketches of machines of flight, and while each is unique, its constituent parts are often analogous to various animal anatomies. Leonardo tirelessly observed creatures of flight, and then performed dissections to discover what enabled them to fly. His careful autopsies are beautifully described and depicted in his Notebooks, and include studies on the wings of birds, bats, flying fish, and dragonflies. He compared the skeletal structure of these animals to that of a human, and then designed machines to turn a man's appendages into wings. Eventually, he deemed bird's flight as the most feasible. Leonardo's studies, thereafter, turned from anatomy to avian kinesiology. Leonardo was not interested in just getting off the ground; he wished for a controlled, continuous flight. He meticulously recorded "birds' turning maneuvers, their ability to maintain equilibrium in the wind, and the detailed mechanisms of active flight." These observations translated to mechanical designs which would enable a man to fly with agility, balance in the wind, and generate enough force to sustain long-term flight. His exhaustive avian study culminated in a small Notebook called ***Codice sul volo degli uccelli***, or the ***Codex on the Flight of Birds***. These studies, however, were too inadequate to replicate a bird's flight. Fritjof Capra, author of ***Science of Leonardo***, explains that Leonardo "felt that, in order to understand the movements of the animal body, he needed to explore the laws of mechanics" (132).

First, Leonardo investigated the forces used in avian flight, but soon realized that these were affected by a multitude of variables. Thus, he began his explorations into the nature of gravity. Leonardo summarized gravitational force in his notebooks nearly two hundred years before Newton published his Theory of Gravitation. It stated that "the natural motion of heavy things at each degree of its descent acquires a degree of velocity. Gravity that descends freely in every degree of time acquires a degree of velocity" (Manuscript M). Capra indicates that "Leonardo is establishing the mathematical law that for freely falling bodies there is a linear relationship between velocity and time" (194). Leonardo attempted to counter the effects of gravity using human force, but had no success. He did, however, again beat Newton to the discovery of the Third Law of Motion: for each action there is an equal and opposite reaction. Leonardo wrote in his Notebook, "See how the wings, striking against the air, sustain the heavy eagle in the thin air on high. As much force is exerted by the object against the air as by the air against the object." Therefore, there did exist a possibility of suspending a man on the air, but his ideas of reciprocal forces and gravitation were not sufficient. He concluded that "In order to give the true science of the movement of birds in the air, it is necessary first to give the science of the winds" (Codex). Leonardo's studies transitioned from mechanics to fluid dynamics (Capra 147).

Leonardo's "science of the winds" culminated in ***The Codex Madrid***. It contains comprehensive theories of the resistance of water and air to moving solid bodies. Leonardo was fascinated by the movement of water and made detailed investigations in current, turbulence, and flow. He sketched the swirling turbulences he observed in streams and rivers, and hypothesized about the vortexes of blood in the aortic valve. He compared the flow of water versus air, depicted the movement of particles in a current, and attempted to quantitatively describe the patterns and properties of liquid in motion (Leonardo). He writes, "Observe the motion of the surface of the water, how it resembles that of hair, which has two movements—one depends on the weight of the hair, the other on the direction of the curls; thus the water forms whirling eddies, one part following the impetus of the chief current, and the other following the incidental motion and return flow" (Leonardo). Leonardo connected his findings to the forces that keep a bird in flight—known today as thrust, drag, lift and weight (Capra 183). Such forces were dependent on the presence of friction, which Leonardo thoughtfully theorized.

Leonardo proposed that friction was dependent on three things: the roughness of a surface, the weight of an object on the surface, and the inclination of the surface (Capra 102). Today, friction is measured as the product of the normal force and a coefficient μ, where the normal force is the product of the inclination of the surface and the weight of an object, and μ is a measurement of an object's roughness. Leonardo's accuracy in this description is astonishing considering the idea of mathematical functions was yet to be born. He applied this idea of friction to his studies on aerodynamics to better understand the relationship between a bird's wings and the air by which it was supported (Capra 205).

Just as he did with friction, Leonardo found recurring patterns in nearly all of his investigations. This pattern recognition began in his study of "pyramidal law." Leonardo's pyramidal law was his attempt to describe "functional" mathematics. Today, a function is "a relation between two sets in which one element of the second set is assigned to each element of the first set" (Collins English). This relationship was yet to be exacted, but Leonardo had realized its importance. He described a correlation between values in terms of triangles, or pyramids. The magnitude of one leg of a triangle affects the length of the hypotenuse. If a second leg is involved (i.e., a second variable), these together determine the length of the hypotenuse. If a third input is used, he uses the analogy of a triangular pyramid, where the height of the pyramid is the result of the three triangular faces. Each component of a situation affected the total outcome, as do variables in complex multivariable

calculus. "Augmentation and diminution in the natural forces takes place in this pyramidal manner…The velocity at which a falling body drops increases in a uniform manner, just as the velocity of a weight thrown vertically upward decreases uniformly. In the same way, force augments with velocity and attenuates with distance. And weight and percussion increase in proportion to velocity. The pyramidal law represents for Leonardo a universal constant" (The Mind of Leonardo).

Pyramidal law led Leonardo to link seemingly unconnected phenomena. Leonardo identified periodicity in nature with startling accuracy. His accomplishments were achieved with nothing but the naked eye, despite the fact that it would take both centuries and the invention of the computer to replicate his ideas. These ideas are complex systems in nature visually represented as "fractals." A fractal is a geometrical representation of a model of chaos theory. Chaos theory is the underlying system used to describe anything undergoing turbulence, or disturbed, random, nonlinear motion like that of clouds, water and air. Just like any other function, a chaotic model can be depicted graphically. These seemingly random and disordered models appear as "a geometric pattern that is repeated at every scale and so cannot be represented by classical geometry" (Collins English). Leonardo illustrated his understanding of such infinitely complex patterns in his Notebooks (Capra 56).

For example, Leonardo marveled at the four geometries of spirals found in nature: convex, planar, concave and columnar. He found that all liquids and gases rotate in these styles, and provides numerical data to explain how "a rapid vortex tends to acquire a void at its center: The lateral weight of the vortex-circulation is two-fold…and such duplication of weight firstly comes into being in the revolving movement of the water and secondly is created on the sides of this concavity, supporting itself there" (Codex). In his notebooks, Leonardo sketched these complex motions. Leonardo drew various substances caught in spiral, likening the movement of water to hair flowing in a breeze, and fields of grass bending as one in the wind. His attempt to find order in the chaos of current is continued today, as scientists attempt to map an underlying structure for dispersal patterns in the world's oceans. Modern investigation utilizes dynamical systems theory, a tool used to understand phenomena that change over time. Studies have culminated in a model called a

Lagrangian coherent structure. These structures are being used in research to improve aeronautical safety, decrease pollution and increase drug absorption (Venkataraman). The depth of Leonardo's studies on fluid dynamics reveals his hand in today's scientific world.

Leonardo spent decades of his life in the pursuit of flight, but eventually abandoned the project. After years of ingenuity, he sadly concluded that man is too heavy to lift himself from the earth. Birds, contrarily, are very light and have extremely powerful pectoral muscles. They are able to generate a force that greatly exceeds their weight, and resultantly can maintain flight without great effort (Capra 186). Leonardo did not, however, see his studies as a failure. He once stated that "the noblest pleasure is the joy of understanding" (Kemp 98). Leonardo's research granted him understanding, yet drove him to seek further knowledge. Flight was not just a dream, but Leonardo's vehicle for acquiring his greatest pleasure.

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Too Smart to Be Nice: "College Girls" and the Women's Education Debate at the Turn of the Twentieth Century

Both popular fiction and public discourse about female college students around the turn of the twentieth century reveal profound societal fears about the effect education would have upon women and upon the United States as a whole. Whether in favor of women's higher education or against it, these texts uniformly address the widespread fear that education posed a threat to femininity. The risks identified by critics were manifold. "College girls" (as they were usually called) would not want to marry, or—even if they did want to—no one would want to marry them. They would become self-involved. They would neglect their domestic responsibilities. They would be unhappy and unfulfilled. In short, the "ideal woman"—a loving, humble wife and mother who was content to devote her life to ensuring the happiness and morality of her family—was at risk of extinction. Despite their many fervent proclamations about the fundamental biological nature of woman, however, an examination of these texts reveals that critics focused their fears not on the overall well-being of womankind, but very particularly on the capacity of women in the upper classes to maintain their social status, marry, and bear children.

Participants in the debate over women's higher education frequently expressed the anxiety that education would deprive the upper-class society woman of the social graces that distinguished her from her inferiors, and even supporters of women's education were not immune to this belief. In ***The American Girl at College*** (1893), a guidebook written to prepare and encourage young women to pursue higher education, Lida Rose McCabe frets about the way college women dress: "American women are said to be the best-dressed women in