Leonardo da Vinci is mainly known for his talents as an artist, with the infamous *Mona Lisa* and the controversial *Last Supper* being two of his greatest masterpieces. In reality, da Vinci was only a part-time artist who maybe worked on twenty paintings of which about a dozen survive[1]. Most of his time was spent as a psychologist, zoologist, linguist, botanist, anatomist, geologist, musician, sculptor, architect, critic, civil engineer, mechanical engineer, and hydraulic engineer. His notebooks consist of subjects ranging from acoustics to warfare and everything in between. He has developed actual and mental inventions that have foreshadowed future technologies by hundreds of years[1]. Da Vinci has invented the future. Other scientists and engineers who have been given credit for his work have advanced many of his ideas, but da Vinci's notebooks confirm that he is the influence of modern science.

Leonardo da Vinci was born on April 15, 1452 in Vinci, Italy. He was the love child of Ser Piero di Antonio da Vinci, a member of a prominent family, and a servant girl[2]. He should have shared in the privileges and responsibilities of family life even though he was an illegitimate child, but there is no evidence of enjoying a normal life with his father's family or any of his relatives except for an uncle who had great interest in his talent. His father basically disowned him after marrying Donna Albieri who was a woman of Ser Piero's level. But when he discovered her infertility, he gained guardianship of Leonardo[1]. Da Vinci's notebooks do not mention much about his father except for his death, which was recorded twice. Each time it was recorded, Ser Piero's age was advanced by one year and his death was on different days.

Da Vinci seemed to prefer the world of nature to the day to day routine of a schoolroom[2]. He also spent more time with the environment than with his friends and family. He suffered throughout his lifetime with deficiencies because of his lack of education, but his genius still surpasses that of even the most educated person.

Leonardo often sketched his impressions of things with realism and precision, providing the earliest reference to the importance of vortices in fluid motion[4]. The dynamics of vortices in water were of great interest to him and he illustrated the circular, spiral and cascading flow patterns of the eddies. These patterns also appeared in his paintings as swirls of hair on the subjects of the portraits[1]. Da Vinci's interest in hydraulics and fluid mechanics influenced others like Evangelista Torricelli, the Swiss family of the Bernoulli's and the infamous Osborne Reynolds. He was fond of examining the relationship between water depth and water pressure. He determined that the pressure at different levels was directly proportional to the weight of water at that level[1]. An experiment he conducted to prove this consisted of holes of equal sizes drilled at different heights in a cylindrical container. The water placed in the container ran out of the holes at different velocities at different heights on the cylinder. The different speeds happened due to the pressure at these heights. He further explained that the difference in atmospheric pressure at different heights was caused by the weight of water. Bernoulli developed this theory into what is now the Bernoulli equation.

Flow visualization much like described above was pioneered by da Vinci over 500 years ago, by observing a free water jet coming out of a square hole into a pool[4]. During this observation, he wrote about the eddying motions of the free jet. "Observe the motion of the surface of the water, which resembles that of hair, which has two motions, of which one is caused by the weight of the hair, the other by the direction of the curls; thus the water has eddying motions, one part of which is due to the principal current, the other to the random and reverse motion." This visualization helped Osborne Reynolds develop the now famous Reynolds number for turbulent decomposition[4].

Reoccurring entries of eddies are all over da Vinci's notebooks. In a section entitled "What Causes the Eddies of Water", he writes about water flowing from a narrow channel and how the eddies occur. He writes,

> "So when water pours out of a narrow channel and descends with fury into the slow-moving currents of mighty seas – since in the greater bulk there is greater power, and greater power offers resistance to the lesser – in this case, the water descending upon the sea beats down upon its slow-moving mass, and this cannot make a place for it with sufficient speed because it is held up by the rest of the water; and so the water that descends, not being willing to slacken its course, turns round after it has struck, and continues its first movement in circling eddies, and so fulfills its desire down in the depth; for in these same eddies it finds nothing more than its own movement, which is attended by a succession of circles one within the other; and by thus revolving in circles its course becomes longer and more continuous, because it meets with no obstacle except itself; and this motion eats away and consumes the banks, and they fall headlong in ruin…[6]"

This same observation could have happened during the free water jet experiment, which also would have led to the Reynold's number.

In 1482, while Leonardo was in Milan, Italy, Ludovico Sforza, who later became Duke of Milan, consulted him in regards to canal engineering. In order to link Milan to the sea, a canal was required. Da Vinci designed a sixty foot wide and twenty-one foot deep canal. A set of hinged gates that met at an angle and formed a watertight joint caused by the water pressure was placed in the canal in order to reduce or increase the flow of water. There were six locks built using Leonardo's system[7]. In his notebooks, Leonardo writes about the canal of Florence. He says that the sluices constructed in the Val di Chiana at Arezzo be constructed in such a way that when there is a shortage of water, the canal will not dry up. He assures that the country, Prato, Pistoia, and Pisa, along with Florence, will be fertilized with a yearly revenue of more than two hundred thousand ducats (gold coins). He also says that this will provide labor and money for the peasants constructing the canal[6]. Da Vinci did not require locks or supports for this canal, but it would require a "constant supply of labor to work them and maintain them.[6]" His notebooks continue on with how to divert a river and protect a house, how to deepen a canal, and how to govern and maintain a river. Designs for equipment that could drain silted waterways were left behind in his notebooks. A double pontoon boat with vertically mounted rotating scoops was one of these designs. The scoops would scrape silt and deposit it on a floating barge that was towed between the pontoons. The equipment used to dredge the Panama Canal is much like Leonardo's designs, except in the twentieth century, the equipment was steam-powered[1]. Many of da Vinci's ideas are apparent and almost common sense to people of today, but these are people who are educated in the sciences. Da Vinci was discovering these things with only an elementary education that did not go past reading and writing. These ideas of da Vinci's are still in use today.

Descriptions of hydraulics in Leonardo's notebooks are always in referral to movement of water, eddies, water waves, falling water, the destructive force of water, floating bodies, efflux and the flow in a tube/conduit to hydraulic machinery[3]. He invented many things in the field of hydraulics including pumps, turbines, hydraulic jumps, side-wheel paddles and of course canals as mentioned before. He possibly even invented the hydrometer, which is a device widely used to measure the gravity or density of a fluid. Within his drawings one will find the design for a turbine to harness hydrodynamic power. In order to rotate a turbine, water flowing or falling from a higher elevation is required. This then turns other contraptions such as mills, drills, or saws. The turbine became a device to power the electric generator that provided electrical energy for homes, cities, and factories[1]. The start of his design for turbines and pumps could have came from a hydraulic machine that is mentioned in his notebooks: "If twelve ounces of water produce thirty thousand revolutions of a machine in an hour we believe that twenty-four ounces will produce sixty thousand revolutions per hour of the same machine if it has the same fall, and that the output will be double what it was at first.[6]" He also has designs for raising water by using a pump or with variations of the Archimedean screw. He basically does this by siphoning. His notebooks say, "Every large river may be led up the highest mountains on the principle of the siphon.[6]" Many of his ideas go back to the "visualization of flow" which helped him pioneer the field of hydraulics.

Da Vinci has also been credited with developing the "velocity-area law", known today as the one-dimensional continuity equation for steady, incompressible flow; also know as the conservation of mass[5]. This was a big discovery that is now used in all aspects of science.

Leonardo did not seem as interested in the air side of fluid mechanics as he did with water. His notebooks are mainly filled with how water works and what water is. There are very few entries compared to those of water. He still studied air though. He mentions eddying winds in the "Atmosphere" section of his notebooks. He writes about when mountains or other things divide the wind, it should come back together and assume the shape of a rectangle. The movement after the reunion is in the shape of a twisted column, which would be an eddy[1]. He also speaks of how the onset of air is much more rapid than that of water. Da Vinci designed parachutes, jets, helicopters and wind vanes. He studied aerodynamics, wave making and the flight of birds. These things are all important in today's time and always will be, but the subject of air still does not amount to that of water and hydraulics.

As said before, da Vinci was a part-time artist, but he used his knowledge of science and mathematics in his artwork. The swirling and spinning motions of eddies were reiterated into the flowing hair of the objects of his paintings. Perspective, proportion, and symmetry are seen everywhere in nature. He used some type of symmetry in every painting and drawing that he did. His book entitled, *De divina proportione* (The Divine Proportion), investigates how everything on a human being is proportional to each other. He used these proportions in his painting as well. Everything he drew and painted all goes back to the idea of nature itself being symmetrical and proportional. Many artists put symmetry and proportion into their artwork, but Leonardo da Vinci made his artwork a science in itself.

Since his death in 1519, Leonardo da Vinci has been and will be an inspiration for all scientists, engineers and artists. He has unified science and art. He has invented and developed so many ideas that the people of today might not be where they are now if it were not for him. His astonishing inventions of turbines, pumps, canals, ship designs, jets, hydraulic jumps and others led the way towards the technology this society knows and looks forward to. Da Vinci was not given much credit for his work while he was alive, but today he is considered a pure genius for encouraging scientists and engineers to experiment, explore and determine what lies ahead for the people of today. Leonardo da Vinci will forever be remembered as the man who invented the future.

References

1 Atalay, B lent. *Math and the Mona Lisa*. Washington. Smithsonian Institution 2004. Pages 314.

2 Baskins, Wade. *The Wisdom of Leonardo da Vinci*. Barnes & Noble, Inc. New York 2004. Pages 87.

3 Boucher, P.F. and Nakayama, Y. *Introduction to Fluid Mechanics*. New York 1999.

4 Gad-el-Hak, Mohamed. *Fluid Mechanics from the Beginning to the Third Millennium*. Tempus Publications. Great Britain 1998.

5 "Gallery of Flow Images." [Date cited: January 13, 2005]. Available from: www.efluids.com

6 MacCurdy, Edward. *The Notebooks of Leonardo da Vinci*. Konecky & Konecky. Connecticut 2003. Pages 1180.

7 "The Man and His Machines." [Date cited: April 6, 2005]. Available from: www.lairweb.org