Last night, as I rounded the corner of Burrows and College, my legs felt the previous 7 miles, and with only ¼ mile left, my breathing was controlled, my blood was flowing, and my heart was pumping. Advances in fluid mechanics have greatly increased our ability to understand the human body, which have led to developments in medical technologies and the overall understanding of human functions. According to The Institute of Aerodynamics in Germany, "The research in the laboratory for bio-medical fluid mechanics focuses on…flows in biological/human systems such as the circulatory blood system and the human airways."[1]

During this semester, one of the first topics covered was fluid viscosity, which introduces the "no – slip" condition. This phenomenon is visible in the human arteries, especially regions surrounding the heart, and is useful for understanding the build up of cholesterol, which eventually leads to unexpected heart attacks. The flowing blood velocity varies quadratically from a central maximum to zero with increasing radial distance, thus it is "stationary" along the artery walls. This "stationary" region causes unwanted particles to gather and reduce the overall blood flow. Once this build up gets far enough into the artery, it restricts fluid flow causing vena contracta and eventually an impenetrable barrier. Images developed using computational fluid dynamics (CFD) allows doctors to see how blood is flowing through selected veins and arteries in the human body. For example, in Figure 1, the blue region represents constricted flow, while the red regions represent steady state flow. After seeing this image, doctors are

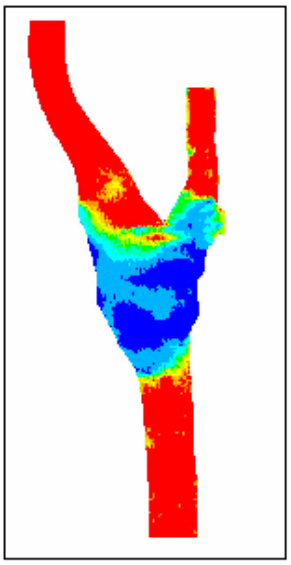

Figure 1. CFD Human Artery

[1] http://www.aia.rwth-aachen.de/index.php?id=341&L=3

accurately able to locate constrictions and prescribe medicines or perform surgeries to help reduce the possibility of heart attacks.

A greater understanding of the human body can be accredited to advancements in fluid dynamics and CFD since the early 1980's. This knowledge has led to significant cultural changes that include education, pharmaceutical goods (medicine, equipment, and procedures), and a more accurate representation of the human body. Fluid dynamics allows researchers to link the causes of artery constriction to certain foods and activities. This then allows medical professionals to educate the general public on methods to treat the current problems and prevent them in the future. Pharmaceutical products, such as specific medicines and procedures have also benefited from detailed fluid flow because they allow researchers to get an in – depth visual understanding of an ailment. With this knowledge it enables experts to develop more specific medicines and medical procedures. An example of this is seen in the diagnosis of kidney stones. Detailed pictures of fluid flow allow for doctors to find the location of kidney stones and accurately track them through the urinary tract through fluid flows instead of standard X – Rays. This advance has allowed researches to develop medicines including thiazide diuretics and procedures such as laser, ultrasonic or mechanical (pneumatic, shock-wave) energy forms to break up kidney stones before they get large enough to cause problems. The American culture is becoming more medically oriented because research is eliminating the gaps and grey areas in the current overall understanding of the human body.

A second biological application for fluid mechanics is the human respiratory system and understanding how oxygen is circulated from the lungs into the blood stream. When we breathe, we inhale oxygen, which travels down through our trachea, bronchi,

and then finally into the lungs. Once in the lungs, the oxygen fills tiny pockets called alveoli, which diffuses the oxygen into our blood. This produces waste gases and carbon dioxide in the alveoli and leave our bodies following the same path the oxygen followed in a process called exhaling.

According to an article written in January 2006 by Louise Elliott, CFD has found increasing applications in the medical fields to better understand respiratory and circulatory diseases.[2] Some of these diseases include asthma, smoke build – up in lungs causing emphysema, and some spinal diseases. A better understanding of air flow in the back of the throat has allowed for advances in the design of inhalers to promote better drug delivery. According to Dennis Nagy, "One researcher with whom we work is studying smoke deposited in the lungs of smokers—to find out what the effects are on lung tissue, how particles are dispersed or deposited, and what gets out of the lungs."[3] While these applications are saving lives and advancing the medical fields, the most interesting advances in the understanding of human respiratory and circulatory systems are happening in the fields of athletic performance and exercise physiology.

Progress in the training regimens for endurance athletes have followed closely with advances in fluid mechanics. In the early 1900's, athletes trained for endurance events, such as marathons and triathlons by simply going out and running, swimming, or cycling the distance they would be competing in, without any real direction. Today, athletes are placed on rigorous training regimens that are coupled with tests that involve basic fluid mechanics. The first of these tests is called the VO_2 Max test. This test measures "…the maximum volume of oxygen that the body can consume during intense,

[2] http://www.deskeng.com/Articles/Applications/Medicine%92s-Fluid-Dynamics-20060110820.html
[3] Dennis Nagy, Vice President of marketing and business development, CD - adapco

whole body exercise while breathing air at sea – level."[4] The test is performed by putting an athlete on a treadmill and hooking them to an ECG machine to measure cardiac activity. During the test, a mask is worn that has a two way valve that delivers oxygen and takes exhaust from the athlete as well as measuring volume and oxygen concentration. The test lasts for a total of 6 to 12 minutes and the difficulty increases throughout. Once oxygen enters the body, it travels into the lungs, and is used by the body. Advances in fluid mechanics have given researchers a more accurate look at VO_2 Max and have allowed for better training regimens in search of better and more efficient ways to improve VO_2 Max.

The first advance in training is running at higher altitude. This increases the blood's ability to supply oxygen to muscles, thus increasing VO_2 Max. It is achieved because at high altitude, there is less oxygen available to be used by the body, so red blood cells are produced to compensate for this depletion in atmospheric oxygen. The life – span of a red blood cell is 90 to 120 days.[5] Endurance runners will train for about a month at high altitude and then return to run a race within a few weeks of their return, while they are still benefiting from the increased number of red blood cells. According to Jack Daniels, "A runner who is not acclimated will lose 10 to 12% in VO_2 max at an altitude of about 6,500 feet and 12 to 15% at 7,500 feet."[6] This decrease in VO_2 Max shows that altitude does affect VO_2 Max and with a better understanding of fluid mechanics comes a better understanding of VO_2 Max, and better training regimens follow.

[4] http://home.hia.no/~stephens/vo2max.htm
[5] http://www.mamashealth.com/run/high.asp
[6] http://www.findarticles.com/p/articles/mi_m0NHF/is_3_21/ai_104209598

Finally, with the introduction of CFD, many other athletic activities fields have benefited. These sports fields include swimming, sailing, Formula 1 racing, ski – jumping, and running. In particular, fluid flow around a body in the water has led to advances in swimming techniques. Underwater swimming constitutes a large part of a race, and efficient turns and starts separate medal winners from the rest of the pack. In order to have efficient turns and starts, drag forces must be minimized. With the advance of CFD, these drag forces can be accurately analyzed, as shown in Figure 2[7], and new techniques can be developed for more efficient swimming. These advancements are great until unethical professionals use this knowledge to construct illegal steroids and medicines to increase sports performance.

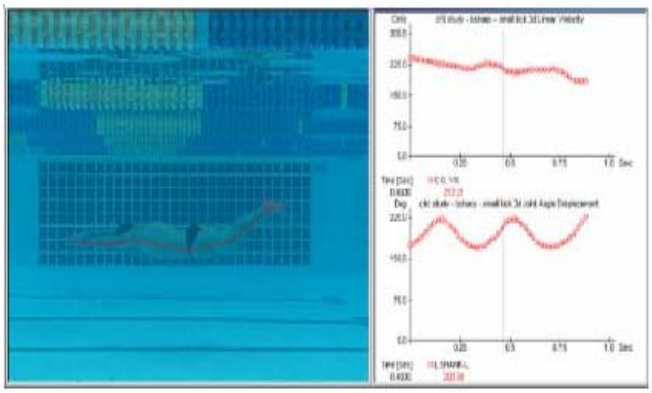

Figure 2. Improved Swimming Techniques

Fluid mechanics are all around us. They govern the natural world we live in, explain phenomena once thought unexplainable, and provide the key to advancement of our society. Not only do fluid mechanics provide a tool to solve the most complex flows through human arteries, they allow us to perfect exercise physiology and training regimens, producing results that would make athletes of 100 years ago gasp. Albert Einstein once said, “We can’t solve problems by using the same kind of thinking we used to create them.” This shows that the problems of today will only be solved by an advance in technology and fluid mechanics.

[7] http://www.coachesinfo.com/category/swimming/355/