The Science of Swimming

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Preface

I would first and foremost like to dedicate this book to my younger self, the girl who first fell in love with swimming long ago. When I was thirteen years old I wrote an essay about my experiences with swimming, and I would like to include it in this book as a testament to the genuine love for the sport that I have always had and still have to this day.

Swimming competitively has been a very important activity to me. I have swum on a competitive year round team ever since I was in fourth grade. Everyday ever since I first started swimming, I have given practice all my effort.

I began swimming in the lowest level on my club team and for the past two years, I have been on the highest level. Being in the top level is not easy. We practice every day, except for Sunday. On Friday and Saturday, we have morning and evening practices. Practicing almost three hours every day gets very tiring, but if it's something you enjoy and are fully involved with, it's not terrible. In fact, I love training for almost twenty hours a week. Some days, I may say I hate it, or that I do not want to go to practice, but once I begin to swim I remember exactly why I first fell in love with the sport.

Swimming is a great way to exercise, get out stress or anger, and so much more. Swimming is an escape that takes you away from reality and brings you to a new world full of peace. Ask any swimmer, and they will tell you that swimming is a part of them. We live for the three hour practices every day, the tough sets, the sprint sets, and the high-intensity dryland training, the chlorine, the team parties, the meets in other states, the championship meets that are more like a swim team vacation, the memories that will last forever, and, most of all, the bonds that can never be broken. Not only are your teammates part of your team, but also they are part of your family. They are your best friends, and biggest competitors.

We live for knowing that in one swim all of your hard work will pay off, and you'll look up at the scoreboard and see that you swam the time you wanted. We live for the races against our best friends. We live for the sound of the buzzer telling us to go. We live for the last stroke into the wall, and the way it feels when you slam your hand into the wall, making sure that every millisecond counts. To non-swimmers, milliseconds mean nothing, but to swimmers they mean everything.

I would not trade my swimming experience for anything in the world. It provides me with a confidence like no other, and my stroke speaks as my voice (Amelia Bothwell, 2013).
Inspired by my thirteen-year-old self, I would also like to dedicate this book to the swimmers who are around the same age that I was when I wrote that essay. Swimming is not an easy sport, and I do not think there is anyone who will rightfully tell you that it is. This book is designed to serve as a tool to guide you to being as efficient as possible in the pool, minimizing all unnecessary stressors in the water. It is my hope that this book will serve as an informative tool that not only aids performance in the water, but also nurtures the love and appreciation that swimmers have for the sport along with all the science behind it.

Finally, I would like to dedicate this book to the amazing coaches who have taught me all that I know about the sport and more. Special thanks to Coach Peter Leib, Natalie Beale, Chris Bley, Dave Linson, and Jack Bower. You each helped to nurture different aspects of my swimming from my technique, to my speed, to my genuine love for the sport.
Chapter 1: The Chemistry of Swimming

The Basics about Water

In order to truly appreciate swimming, you must first have a basic understanding about the chemical make up of water.

Water, or $\text{H}_2\text{O}$, is formed from two Hydrogen atoms bonding with one Oxygen atom. Atoms are the building block of elements, which are found on the periodic table. The bond between these three atoms is a polar-covalent bond. This means that pairs of electrons are unequally shared between two atoms.

As a result of its polarity, water has the capability to dissolve other polar substances very easily. This is why sugar dissolves when mixed in water. Sugar is a polar substance. On the other hand, oil does not dissolve in water since oil is a non-polar substance.

Water can be in the form of a liquid as it is when it is in a pool, but it can also be in the form of a solid as ice or in the form of a gas as condensation.
Chemicals in the Pool

**Chlorine** is the most commonly used chemical found in pools. When poured into pools in a powder mixture, the chlorine breaks apart and forms different chemical compounds. These chemicals work to kill bacteria and other harmful organisms by attacking and destroying lipids, the part of the cell that stores energy, provides the cell structure, and sends the cell’s signals, and enzymes, the part of the cell that speeds up chemical reactions. By destroying these parts of the cell, the bacteria and microorganisms are left harmless.

Although chlorine works to keep you safe, when mixed with natural body oils, chlorine releases chloramines which can irritate the lungs when inhaled in high amounts. In order to avoid contributing to the amount of chloramines in the air, you should take a shower to rinse off the oil sitting on your skin prior to entering pools.
Chapter 2: The Biology of Swimming

Lactic Acid

As you exercise, blood-sugar levels drop and as reserves of glycogen are used up, lactic acid builds up. Lactic acid is a result of glucose metabolism, the process by which sugars are coverted into ATP, the energy that is needed to perform physical activities. When lactic acids builds up in your muscles, you often experience fatigue or muscle cramps.

There are several methods to decrease and relieve the soreness caused by lactic acid build up.

The first method is elevating your legs. Find a wall surrounded by space to lay down. Set a towel or mat on the ground. Rest your back against the towel or mat. Place your legs up against the wall and move as close to the wall as you can until your legs are perpendicular, or about 90 degrees, in relation to your torso. Once you are positioned, relax for as long as you need. This will drain the acid build up from your legs and help blood circulate.
The second method to decrease the soreness is by **foam rolling**. Similar to elevating your legs, foam rolling allows the lactic acid build up to be broken up.

The final, and most important, method to get rid of lactic acid is through **hydration**. When lactic acid builds up, muscles also generate lots of heat. Water helps to take the heat away from the muscles, alleviating the effect of fatigue.

**Muscles and Movement**

Swimming is one of a few sports that encompasses the use of nearly all the muscles in your body. It uses both the **voluntary** and **involuntary muscles**. Voluntary muscles are muscles that you have the ability to control, whereas involuntary muscles work with or without your control.

The primary involuntary muscles that are key to swimming are your **heart** and your **diaphragm**. Your diaphragm helps your lungs take in oxygen when you breathe and put the oxygen in your blood. Your heart then functions to pump the oxygenated blood throughout your body, providing muscles with needed oxygen.

Each stroke utilizes nearly all the same voluntary muscles, however, they are driven by different primary muscles and are used in
different movements. The muscle groups that are used in freestyle are circled in the diagram below:

![Diagram of muscle groups](image)

**Arm:** Thenars (hand muscle), brachioradialis (forearm flex muscle), flexor digitorum profundus (forearm extend muscle), biceps, triceps, deltoids (shoulder muscle)

**Neck:** sternocleidomastoid (neck muscle)

**Trunk:** pectoralis, serratus anterior (side muscles), external oblique (outer ab muscles), rectus abdominus (abs), latissimus dorsi (back muscle), trapezius, spinus erectus (muscles that support your spine), teres major, teres minor, rhomboid major, rhomboid minor (all of these "major and minor" muscles help make up the shoulder muscles), gluteus maximus (rear-end muscles), abductor magnus (groin)

**Leg:** quadriceps, hamstrings, gastrocnemius (calf muscle), tibialis anterior (shin muscle), flexor digitorum brevis (foot muscles)

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1 Image and key courtesy of Chris Mann, blogger swim coach. See http://chrismannswimcoach.blogspot.com for further information.
Breathing

Breathing is a critical part of swimming. If you do not get enough oxygen intake, then your muscles will not function as needed. In order to make sure that you are able to get enough oxygen into your system, you must make sure to exhale completely by blowing out the carbon dioxide in the water after taking a breath in. By exhaling, you are decreasing air in the lungs, making your next breath more effective and increasing the span of time you can allow before taking your next breath.
Chapter 3: The Physics of Swimming

Buoyancy

According to the ancient Greek inventor and mathematician, Archimedes, any body that is either completely or partially submerged in a liquid or a gas at rest experiences an upward, **buoyant force** that is of equal greatness and degree as the weight of the liquid or gas that the body displaces, or moves. This is known as **Archimedes’ Principle**.

On account of Archimedes’ Principle, we are able to float. The water presses back against the force that your body weight applies to the water.

In addition to keeping us afloat in the water, buoyancy causes you to feel 90% lighter in the water. In other words, the buoyancy of water creates a decrease in body weight. Due to lungs filled with air, you actually weigh *less* than the water. This also helps you to float, because like a balloon filled with Helium gas, when your lungs are filled with air, they help carry you to the surface naturally.
Velocity and Acceleration

**Velocity** is a physical quantity that has both magnitude and direction. It refers to someone or something’s “speed.” As you swim, velocity is increased as you press down on your hands to pull through the water or as you press down with your legs to kick. The more **pressure**, or force, that your arm or leg applies to the water, the faster rate you move forward.

**Acceleration** is defined as the rate that an object changes velocity. When you dive from a start into the pool, you are moving forward due to acceleration. As you swim, you are constantly losing velocity. Essentially, swimming is not about who can swim the fastest, but rather, who can lose velocity at the slowest rate. It is through fine tuning stroke techniques that this can be achieved.

Force

As you swim, there are several significant **forces** that are affecting your performance. The primary force that restricts performance in the pool is known as **drag**. In order to overcome this force, many elite swimmers wear tight-fitting technical suits and caps, in addition to shaving unnecessary body hair. This helps to minimize the effects of drag, making them as swift as possible in the water.
As depicted in the diagram below, being as **streamline** as possible in the water also helps to reduce drag. In order to achieve this, it is important to focus on factors such as having proper **head positioning**. Your head should be tucked close to your chest so that water can go over the back of your head and neck as opposed to hitting your face, causing you to slow down.

![Small drag in streamlined position](image1)

Gravity and **static friction** are two forces that are important when diving. They help stablish you on the block, keeping you from falling off. Gravity pushes down on you and the block as a force is applied from the block pushing back against the force of gravity.

Once you dive off the block, it is gravity that causes you to enter the water. As you swim, gravity continues to act against you, pulling
you down, however, buoyancy helps to keep you afloat as previously discussed.

**Turns**

**Newton’s First Law of Motion**, also known as the **Law of Inertia**, states that “an object at rest stays at rest and an object in motion stays in motion with the same speed and in the same direction unless acted upon by an unbalanced force.” On account of this law, when you flip-turn, your motion temporarily stops as you hit the wall and then picks back up as you change direction and push off of the wall.
Momentum

Objects that are on the move are defined as having **momentum**. As you kick, the downward **thrust**, or force that makes you move forward, creates an **action force**. This motion causes the water to exert a reaction force which pushes you forward, keeping you moving with momentum.

Underwaters

Though only allowed for the first 15 meters per lap, **underwaters** are proven to be the most efficient method of moving through the water. Moving your body in an S-like wave, you push push the water and create a thrust. This occurs on account of **Newton’s Third Law of Motion** which states that “for every action, there is an equal and opposite reaction.” In the same manner that kick propels you forward, underwaters help you move quickly and
efficiently through the water.

Backstroke Starts

Just as head positioning is important to being streamline, having proper head positioning during a backstroke start helps to set you up for the proper angle of entry into the water. Unlike streamline, however, in order to achieve the optimal angle of entry, your head should look forward so that your neck and spine are in a straight line. Additionally, your arms should be slightly extended rather than pulled in close to your body.

This positioning lines you up in such a way that you are able to send yourself backwards farther as opposed to sending yourself high out of the water and straight to the bottom.
Chapter 4: The Psychology of Swimming

Mental Training

“Mental toughness.” I am sure that this is a phrase that all swimmers have heard at least once, but what does it mean?

In order to have success in the pool, it is just as equally important to be in good mental strength as it is to be in good physical shape.

In order to achieve optimal mental strength, you must start by setting long and short term goals for yourself. Make a plan as to how you will achieve these goals, including process goals. Naturally, there will be obstacles and set-backs that may cause you to struggle to achieve your big goals, but by setting process goals and holding yourself accountable to those goals, you will be able to see your progress and growth towards achieving your big goal.

Visualization is another tool that can help improve mental toughness. Visualization is a technique that can help lessen nerves that are felt before a race. In order to practice this technique, you must find somewhere quiet where you can sit or stand without being distracted. Once in a good spot, close your eyes and imagine yourself swimming at a meet or in practice. While visualizing, imagine any scenario whether it is good or bad so that you are
prepared for anything that may come your way. By practicing races in your head, you are more prepared when you step up on the block.

The Power of Positivity

Having a **positive** mindset is another aspect of mental toughness. If you find yourself struggling at training meets or after hard practices, try sitting down and writing out any three positive things you can think of that you did. This can be anything from a nice interaction with a teammate, to having strong underwaters, to closing a race well, or anything else that you can think of. By writing this, you are increasing positive emotions and decreasing negative ones. It is proven that expressing **gratitude** improves health, decreases stress, and helps us to deal with hard times.
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