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"Learning the secret of
flight from a bird
was a good deal like
learning the secret of
magic from a magician."
– Orville Wright

Master Books®

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Best-selling author, TV co-host

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FOREWORD

My first experience in complex design began with my dad. He was always the guy who could fix anything and was forever tinkering in his workshop. He worked for several companies and had several inventions before working as a national products safety inspector.

As a young boy I enjoyed seeing how things work and began deconstructing them to see the mechanics. I was employed part-time during high school at an auto shop and wanted to transition it to a full-time job. I had no plans to attend college or university.

My dad, however, encouraged me to take a college course. He valued education, and I respected him, so I took a two-year course in avionics. I loved it and fully immersed myself in basic science and electronic theory.

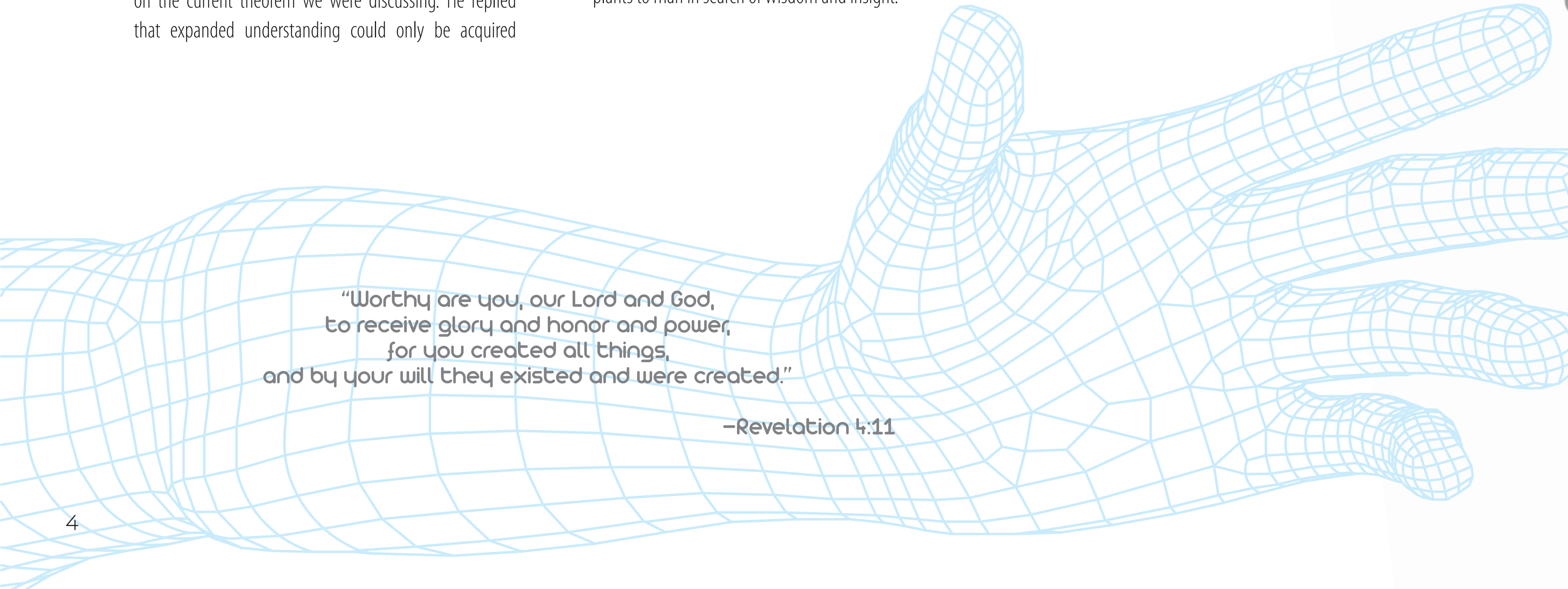
During one of my courses, I asked my professor to expound on the current theorem we were discussing. He replied that expanded understanding could only be acquired by attending university. So I applied to study aerospace engineering the next semester. To date, it's been 22 years and three different countries that I've been blessed to work in as an aerospace engineer.

Engineering is a complex and dynamic field that drives our modern culture with technological advances. They make our lives better, according to *Merriam Webster*, "through the application of science and mathematics by which the properties of matter and the sources of energy in nature are made useful to people." In short: engineers discover better, faster, and more innovative new products that improve our lives.

Engineering is imagination-and design-driven. Nowhere is this more evident than the study of the natural world applied to the science of engineering. Engineers have long examined God's creation to understand and mimic complex and proven mechanics of design. They have plumbed the depths of the natural world, encompassing insects to plants to man in search of wisdom and insight.

The simplicity yet intricacy of how God's designs work and how He manufactures complexity in nature astounds and inspires engineers in hypotheses and designs that could not be formed otherwise. We can only marvel, admire, and maybe copy some examples our Creator has left for us to discover.

— Jeffrey Seto, B.Eng



"Worthy are you, our Lord and God,
to receive glory and honor and power,
for you created all things,
and by your will they existed and were created."

—Revelation 4:11

INTRODUCTION

"In the beginning, God created the heavens and the earth."

—Genesis 1:1

THE SIGN OF DESIGN

When skeptics ask for a "sign" that proves the existence of a Creator, the sign to look for is the sign of nature's design. When Sir Isaac Newton said that atheism was "sense-less," he chose his words carefully. Those who look at the unspeakably wonderful design of nature and don't see the hand of the Designer are truly sense-less. They're not using their God-given senses of sight, sound, touch, taste, and smell. Nature screams of God and, for some reason, they turn a deaf ear, a blind eye, and a closed mouth.

Let's play the game of atheism for a moment by surmising that there's no evidence that the book you are holding had an author or a designer. There was nothing, and for some reason paper evolved. So did glue, ink, and cardboard. Then, over millions of years, the book fell together into a spine, a beautifully self-designed cover, saddle-stitched pages with consecutive numbers on each page. Then intelligent information fell from somewhere and formed itself into straight lines of text and coherent sentences with bold headings and indented paragraphs — all in perfectly spelled English. But there's more to this fantasy. Each photo you see in the book evolved from nothing into a beautiful picture, with text explaining each one.

What sort of senseless person could believe that? An atheist could. I have talked to many atheists who believe that given "time" anything is possible. There is a word more descriptive than Newton's "senseless" for such a person. The Bible says that he is a "fool" (see Psalm 14:1).

THE DOOR OF LEARNING

We often boast of human beings "creating" different things, and yet we can't create a heart, a living hair, a frog, or even a grain of sand . . . from nothing. We can re-create (using God's material), but in reality we cannot create a thing. That's God's business, and when we realize that, it is humbling — and nothing opens eyes like humility. Humility is the door of learning. A know-it-all can't learn a thing.

Humility is also the key to reconciliation. This is so evident on the freeway. Have you ever been cut off by a thoughtless driver? You fume at him, but when the driver looks directly at you, lifts his hand in a humble gesture of contrition, and mouths, "I'm so sorry," your anger dissipates just as quickly. You feel like calling out, "That's okay! I understand. I do silly things myself all the time. Let's be friends!" Humility reconciles man to man, and man to God.

Psalm 34:2 talks about the humble man or woman and his or her reaction to praise. It says, "My soul shall make her boast in the Lord: the humble shall hear thereof, and be glad." If you want to see pride rear its ugly head, boast about something God did for you — perhaps something you believe was an answer to prayer, and listen to the proud heart attribute it to luck, coincidence, fate . . . anything but God.

Or talk about how awesome God is in His creation to a proud person, and listen to him give Mother Nature praise. There are even some who would rather believe that nothing created everything and give no praise at all to anything than give God one ounce of glory.

THE ANT SCHOOL

Let's humbly look at one tiny part of creation. Solomon encouraged the sluggard to go to the ant and consider her ways, and be wise. If we do that we will see that the tiny insect is incredibly industrious. We rarely see one standing still. It's good (and wise) to be inspired to work by the ant's example; however, there's another reason we should go to the ant and consider not just her ways but her very being.

There are about 20,000 different types of ants. Consider how they are all similarly designed with three main body parts: the head, the thorax (middle portion), and the abdomen (rear portion). The outside of its body is covered with a protective armor called the "exoskeleton." Now contemplate how each one has incredibly complex compound eyes, a mouth that can distinguish different foods, amazing claws that grip, feet that walk, an instinct to make a nest, to recognize a mate and procreate, to take care of its young, to identify things that are profitable for the ant hill/farm, and the ability to sleep, eat, and digest food.

Each of the 20,000 different types of ants has a nervous system that contains its multifaceted, tiny, but brilliant brain. Each one has a heart that is a long tube that pumps a special type of blood through its body, as well as an intricate muscle system that works the claws and legs. It has the ability to detect danger and can instantly respond to the call to battle and unify with an army to ward off attackers. It can also unify to attack and completely devour its prey, sometimes in moments.

So who tells the ants to attack in such unity, and where do they get their training to know what to do? The answer is that most of their behavior takes place because they are pre-programmed in their DNA to act the way they do, in the same way that the programming in our DNA tells our blood to clot. However, they do have some schooling taking place, where they learn different skills.

Many animals can learn behaviors by imitation but ants may be the only group apart from mammals where interactive teaching has been observed. A knowledgeable forager of *Temnothorax albipennis* leads a naive nest-mate to newly discovered food by the process of tandem running. The follower obtains knowledge through its leading tutor. Both leader and follower are acutely sensitive to the progress of their partner, with the leader slowing down when the follower lags and speeding up when the follower gets too close. [1]

Perhaps you are thinking, Wow! Ants are incredible! But we should instead be thinking about how utterly incredible God is to have the ability to conceive the thought of the ant, and then to create it.

Do you ever think about God? Do you ever consider how the ant is just a tiny part of the millions of different insects and that they all have amazingly intricate features?

Do you ever think about flies, or eyes, or skies, or birds, nerds, words, or trees, bees, and even knees — with their remarkable ball-and-socket joints and their smoother-than-oil synovial fluid that keeps everything moving efficiently? Have you ever looked deeply into your own eyes in a mirror or studied the dexterity of your hands and thought about how you are "fearfully and wonderfully made"?

Our problem is that we don't consider creation in any real depth, and we give even less thought to the Creator. We are truly blind, and we will stay in that state until we humble ourselves and have our eyes opened through the new birth (see John 3:1–6). When I became a Christian at the age of 22, everything suddenly looked different. I was no longer blind. The trees looked different. The sunrise looked different. I looked at all of nature differently. I saw that every branch, every tree, every leaf was lifting up its arms in praise to the God who made it! The early morning birds sang His praises. The colorful and fragrant flowers radiated with vibrant life and opened their faces to His glory. The tiny ant screamed of the genius of Almighty God. Everything looked different because I was different. I was a new person with a new heart and new desires, having the eyes of my understanding enlightened. In a moment of time I was no longer blind, deaf, and dumb . . . and so my soul is about to make its boast in the Lord. I hope you hear what this book says and are glad — because you look beyond the painting and see the Painter.

—Ray Comfort

1. SWIM LIKE A FISH: COPYING SHARK SCALES

Swimming like a fish might get you on the Olympic swim team, but having a swimsuit that mimics a fish might improve your time there, too. This is the beauty of the science that studies the natural world to find solutions. The shark, for example, is an enigma. It is the killer of the seas and known for its stealth. However, it would not seem to be the natural choice to study swimming like a fish due to its bumpy scales called placoid scales, also known as dermal denticles (skin that looks like teeth).

We generally think that smooth, torpedo-like surfaces allow you to swim like a fish. It's hard to reconcile that the shark's placoid scales would allow smooth swimming, but we know sharks are strong swimmers.

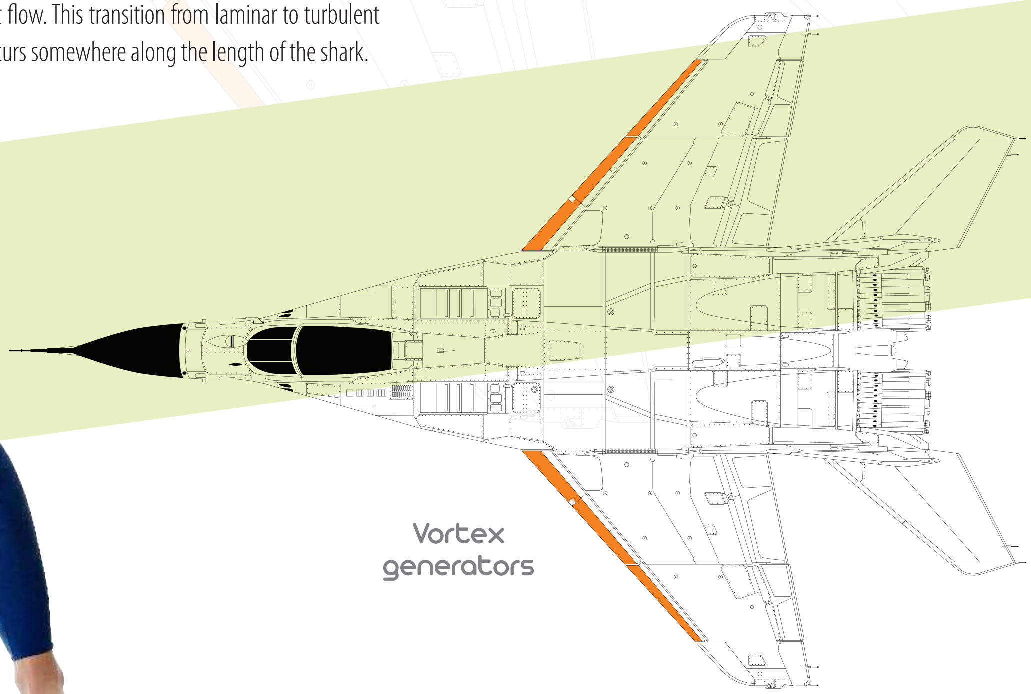
The boundary layer is an area that lies closest to the shark's body and affects how water flows past a body (shark/swimmer). This layer transitions from a laminar (smooth) to a turbulent (rough) flow along the length of the body. The transition from laminar to turbulent flow is inevitable with any moving body, and the area in which it will occur is of greatest value to streamlining a body.

The length of the shark to the region where its body protrudes outward has smooth laminar flow. Normally after any protrusion, flow separation occurs and results in turbulent flow. This transition from laminar to turbulent flow occurs somewhere along the length of the shark.

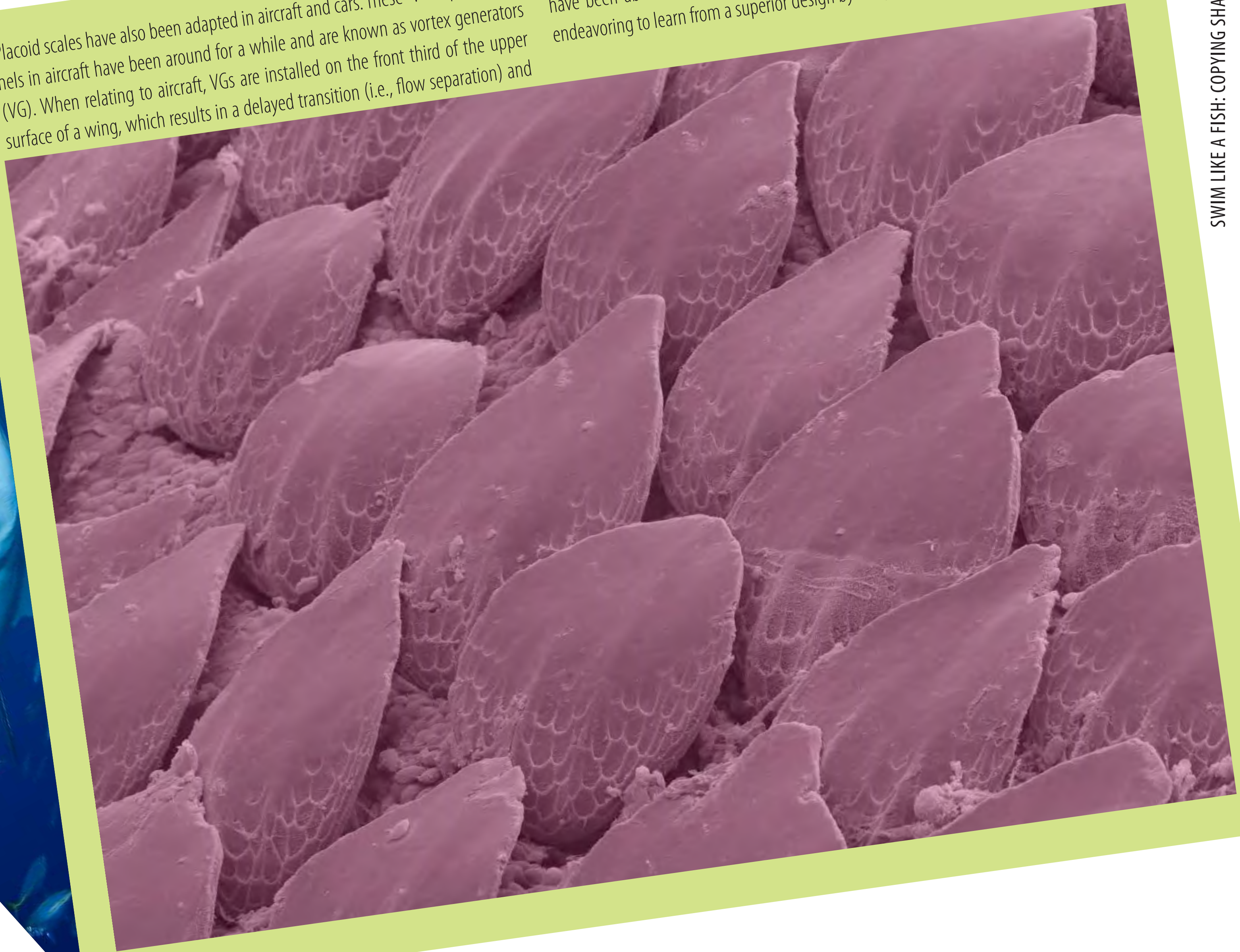
Engineers calculate and determine the position of this transition and are able to move this transition region further toward the back. The outcome is extended laminar flow, which invariably lessens drag, resulting in a faster-moving object.

Although swimming like a fish is a little more complicated than just the boundary layer, Speedo™ designed FastSkin®, a swimsuit that mimics the shark's placoid scales with a sharp-edged riblet design. Some studies have even suggested that these have no effect since the microstructure of sharks' skin is more complicated and the key to their speed has not been unlocked, but you wouldn't know that by looking at the Olympic teams when these suits were first introduced and swimming speeds were improved. Since then we have seen many advances focused on increasing speed and retaining less water to gain an edge in competitive events such as Olympic trials and the official games.

Made of fabric that mimics sharkskin, Fastskin® remains one of the fastest choices in the pool. Designed to repel water and compress the body.



Placoid scales have also been adapted in aircraft and cars. These "V-shaped" channels in aircraft have been around for a while and are known as vortex generators (VG). When relating to aircraft, VGs are installed on the front third of the upper surface of a wing, which results in a delayed transition (i.e., flow separation) and an increased region of laminar flow, making the airplane move faster. Engineers have been able to increase efficiency on land, in the air, and in the sea when endeavoring to learn from a superior design by a superior designer.



2. BODY ARMOR OF THE FUTURE — STRENGTH OF FISH SCALES

Thoughts of body armor likely conjure up images of a medieval knight donning a rigid and impervious suit of armor. Suits of armor in the Middle Ages were entirely made of steel and formed to the shape of the knight. It effectively offered protection, but the cost was mobility as movement proved heavy and difficult.

The quest for military and law enforcement officers is protective body armor that is flexible, lightweight, and capable of protecting the body from ballistic projectiles. A solution may lie in the Amazon basin of South America. Here resides the native arapaima fish. The arapaima is one of the world's largest freshwater fish and can reach lengths up to 9 feet and weigh up to 440 pounds. It isn't the size but the exterior scales of the fish that has stirred creative new ideas for body armor.

The arapaima scales can reach lengths up to four inches long and are arranged in an overlapping layout along the longitudinal axis of the fish. Its intricately designed scales are composed of different materials, unlike the single layer of steel in medieval armor. Moreover, the scales have multiple layers with orientation properties to maximize strength. A closer look at these layers sheds light on why these fish can withstand piranha-infested lakes.

External Layer:

Thickness	600 micrometers
Composition	Made up of a hard, mineralized material

The external layer's surface resembles a wavy texture similar to the corrugated center portion of a cardboard box. The lower valleys of the wave in the scales have slits. This shape provides flexibility to the scale, which is unexpected if you were constructing a surface impervious to attack. That is, until you consider how it works with the internal layer.

Internal Layer:

Thickness	1,000 micrometers
Composition	Soft collagen fibers

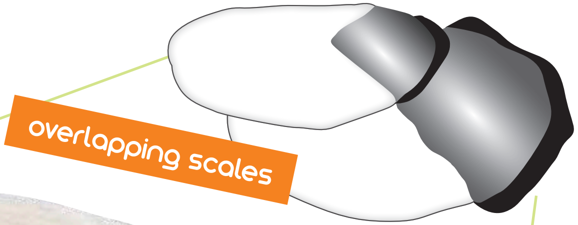
The internal layer is made up of multiple layers of collagen fibers oriented at varying angles with respect to each other. The fibers are long and thin with a strong and weak side. The weak side is the long portion of its cross-sectional area.

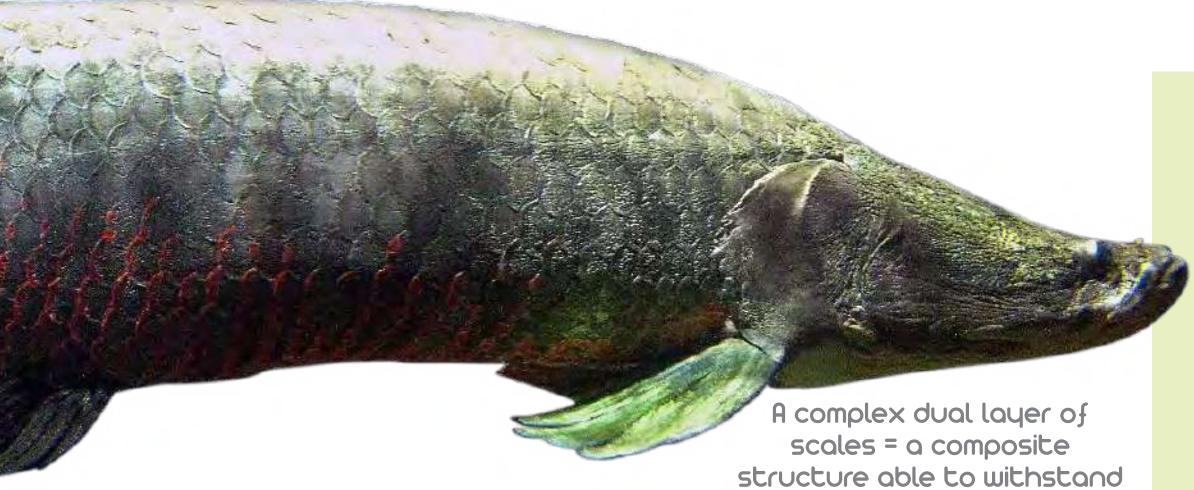
It is similar to a plank of wood. It is easy to split wood along its grain, but going against the grain isn't easy. If you have children in martial arts, please know that the spinach you gave them for dinner didn't contribute when they impressively "split" that board in their class. No, it's most likely they were given thin breaking boards with the grain of the wood cut so that it would be parallel to the striking hand.

The opposite is true and observed on the arapaima. Each layer is aligned at different angles to the previous layer, culminating in a stacked structure that exhibits strength in all directions based on the alignment of each layer. What is remarkable is that each layer possesses characteristics of the other layer (in a lower magnitude).

The combination of these scale layers adds its own uniqueness to the overall strength and mobility.

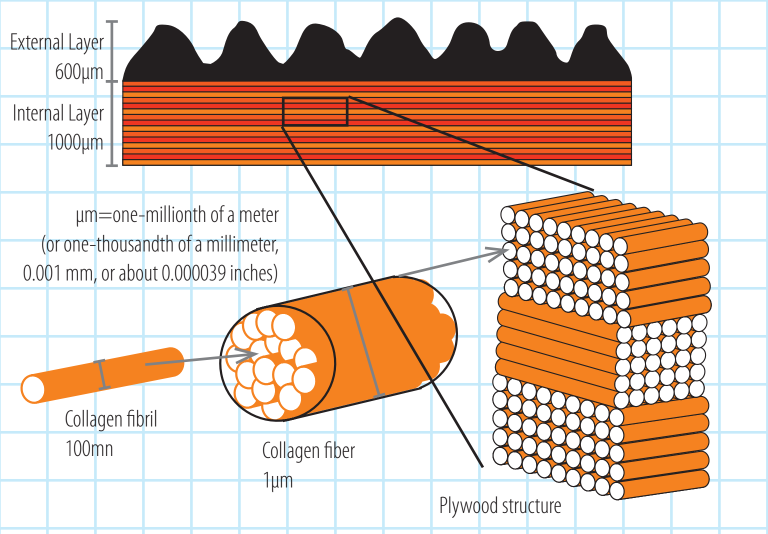
This type of layered multiple material is classified as a composite structure. Together, these layers have been the bio-inspiration at Jacobs School of Engineering at UC San Diego. The result may be a future composite body armor that is both impervious and flexible.



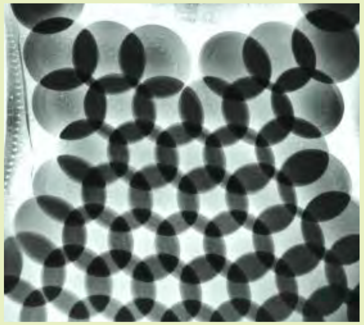


A complex dual layer of scales = a composite structure able to withstand piranha-infested waters.

A durable design creates strong "armor" for protection.



Seen in the x-ray of Dragon Skin® body armor designed by Pinnacle Armor.
▽



3. STRONGER THAN KEVLAR® — SPIDER-WEB STRONG

It is not only fish being studied for applications related to strength. Spiders are intelligent creatures and have been long studied, admired, and captured in folklore. They have been epitomized in myth, movie, story, and fable. Many hold fond early memories of "Itsy Bitsy Spider" as a favorite children's nursery rhyme. *Charlotte's Web* is a beloved novel from youth, and Spider-man has captivated many an imagination in comics, TV, and movies.

The focal fascination and uniqueness of a spider is inarguably its web. The beautifully intricate interwoven fibers are a marvel to science. The tensile strength of a web is really the stuff of legend. In the world of fibers it is tensile strength that sets one fiber apart from others. Fiber strength is determined when stress is applied, such as pulling from both ends similar to a tug of war. Engineers call this value the ultimate tensile strength, that is, the maximum stress (PSI) that a material can withstand before it breaks.

Every material has a tensile strength, even the seemingly delicate spider silk. Below is an example of comparative metals. The PSI numbers represent the maximum load that the material can handle per square inch. The higher the PSI, the stronger the material is.

Stainless Steel	15-5PH, ½" thick	154,000 PSI
Titanium	Ti-6Al-4V bar, ½" thick	135,000 PSI
Aluminum	7075-T651, ½" thick	75,000 PSI
	SPIDER SILK	253,816 PSI

Spider silk may seem fragile, but the average spider silk is a whopping 253,816 PSI, almost 100,000 PSI stronger than stainless steel.

Okay, so the spider silk has great PSI. But what is the spider silk load equivalent and why do you need to calculate that? Load is one of the characteristics that engineers also use in determining strength to make sure things are strong and don't break easily.

Once we know the ultimate tensile strength of spider silk, we can then determine the actual load (pounds) it can handle by using the following equation:

Load (lbs) = Ultimate Tensile Stress (PSI) X Area (square inches)

We can formulate proper models and understanding using both PSI and load numbers to understand in real time the strength of spider silk. As an example, let's assume that we have a strand of spider silk the same diameter as a human hair (.00071 inches, area of hair = .000000396 square inches): **Load = (253,816) X (0.000000396) = .10 lbs.**

This means that if we were to pull on a strand of spider silk the diameter of a human hair, it would be able to withstand a load of 0.1 pounds before it breaks. If you had 1,000 strands of hair you would need 100 pounds to break the strands. These numbers could make even the strongest of strong men cry.

In terms of available materials to date, only Kevlar® (invented in 1965) had a greater tensile strength. It is commercially produced into things like bulletproof vests. However, it was recently discovered that there is a Malagasy spider with over ten times the toughness of Kevlar®. This recently discovered spider silk is the strongest known biological material to date. With super numbers like that, it is no coincidence that science is trying to invent tougher materials by mimicking the super structure of a spider's web.

Malagasy spider

Bulletproof vest

4. PINECONE FASHION COMING SOON TO A MALL NEAR YOU?

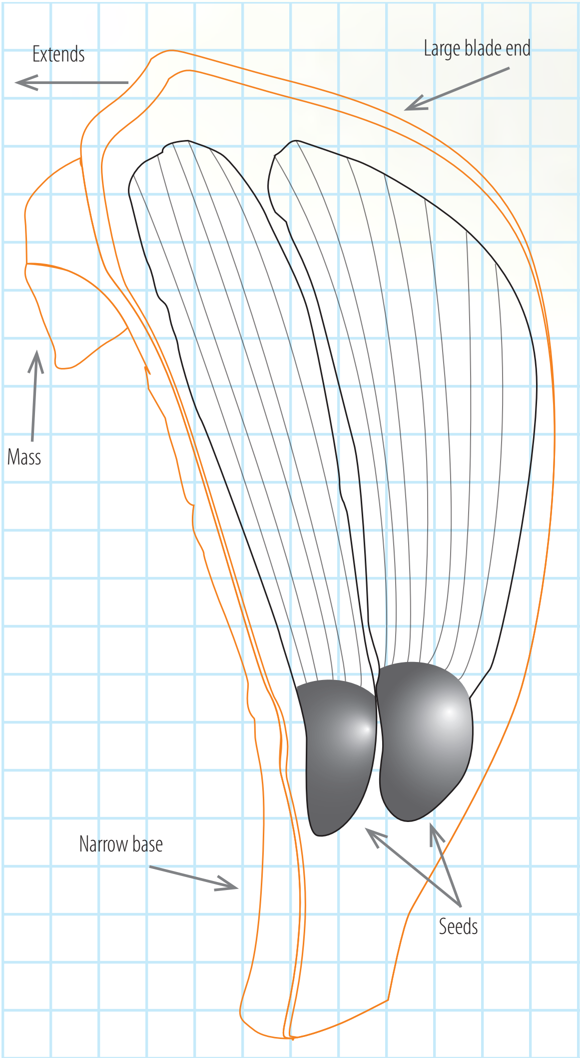
I remember looking at this subject as I was writing and wondering if it was a joke. After carefully researching the humble pinecone, I realized that this was indeed a seeming contradiction to the laws of science, which has raised interest in the research of the pinecone (J. Seto).

The quick science is this: We know that as moisture is removed from an object, what proceeds is a physical reduction in overall size. Dehydrated foods are a great example. A grape shrinks when removed of its water content and becomes a raisin. You pack these when you go camping because they take up little space in limited areas like your hiking bag and car.

Not all objects shrink by the same volume. A rock removed of moisture will never turn raisin-like; in fact, we probably wouldn't see much difference in the physical appearance. Can we assume the same would hold true for a pinecone?

The logical conclusion is that when the weather is warm and dry, the scales on the cone would shrink and contract and the pinecone would close. But the opposite is true because of the geometric shape of each of the pinecone scales. A closer look at these scales reveals that each scale is narrow at the base and fans out to a larger blade at the end. The larger blade end has a mass on the lower side, which acts as a counterweight to cause the scale to extend downward.

This is because there is something special lying on the top of the scale. There are two seeds that are waiting to be released when the pinecone opens. Since the seeds are a different composition relative to the pinecone, the net effect is a difference in the overall shrinkage.



Remember how there is a variance in how different things shrink? Pinecones and their seeds shrink and contract at two different levels. The seeds shrink less than the pinecone and cause more shrinkage to occur at the lower face of the scale as compared to the inner (seed) side of the scale.

Here is how the sequence of this shrinkage works in real time:

1. Dry weather causes moisture to be evaporated from the scale and seeds.
2. The narrow base begins to shrink/contract, in addition to the entire scale and seeds.
3. Due to both the mass on the end and the two different shrinkage amounts, the tip of the scale extends downward, resulting in the opening up of the pinecone to allow the seeds to be dispersed.

The pinecone is one example of a bio-inspired mechanism being copied for smart fabrics. Others include the lotus leaf (water repellent/self-cleaning), algae (UV-protection), and the mimosa plant (touch sensitive).

Relative humidity activates a movement in the structurally functional fabric to help wick away moisture. Changes like this, as a direct result of absorbing or attracting water are called hygroscopic.[2]

Plants survive by spreading their seeds. The pinecone does this when the weather is dry so that the wind can pick up the seeds, carry, and disperse them. The pinecone is not a rebel to the laws of science but an ingenious design of God that has caught the attention of researchers who are developing adaptive fabrics that will open and close (pinecone style) as the weather gets warmer. How cool is that?

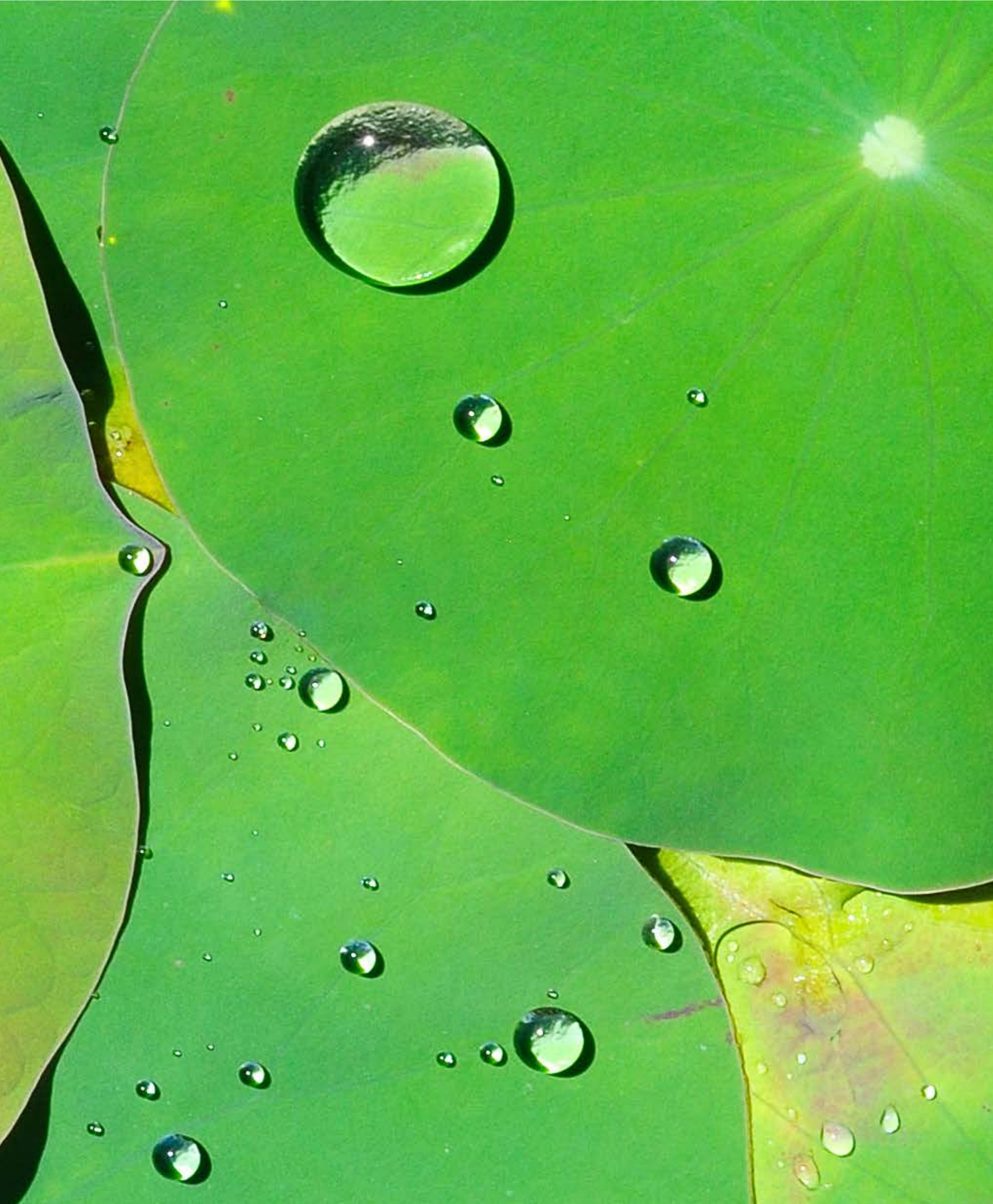
5. CLEANING LIKE A LOTUS LEAF

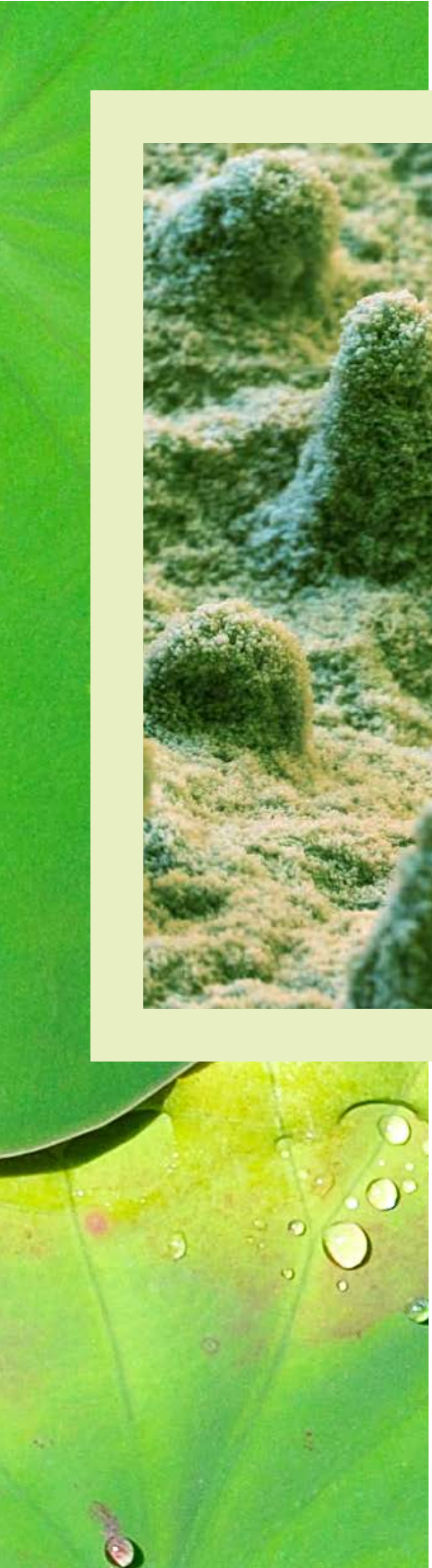
The natural world we live in offers many beautiful things that seemingly do not offer man any ideas for functional living. Leaves surround us with beauty and we know the function of trees to the air we breathe. But did you know leaves are quite remarkable in the applications they can provide us? The lotus leaf is one such specimen.

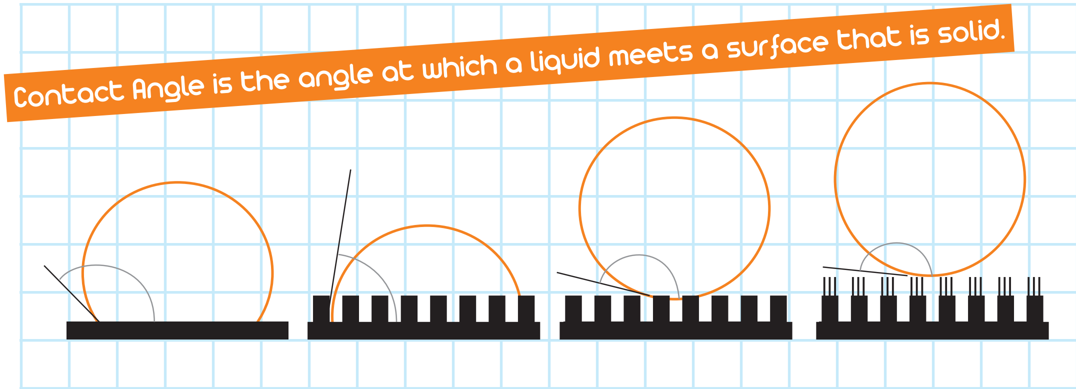
The lotus leaf is self-cleaning, thanks to a surface that consists of microscopic bumps. Each bump is covered with nano-scaled tubes that project from the surface of the bump.

As water droplets fall on the lotus leaf, the amount of contact area is balanced by these tubes and bumps. Reducing the amount of contact area causes instability of the water droplet because of the random locations of both the bumps and tubes. The result is that the water droplet will begin to roll along the leaf. This deflects the leaf downward and casts the water droplet off the leaf. The bumpy texture of the leaf with weight of the water drop mitigates the drop toward the unsupported end, thus falling off.

Observation of God's genius in man's naturalistic environment has propelled companies to formulate new ideas based on this nanotechnology of fluid repellency and attraction. This could change the way things are coated to either repel or attract moisture on both organic and nonorganic materials. The potential for self-cleaning is emerging in fields such as clothing and paint, without extra expended energy.







Some plants show contact angles up to 160° and are called super-hydrophobic, meaning that only 2–3% of a drop's surface is in contact. The higher the contact angle the higher the hydrophobicity of a surface.

◁ Water drops (orange) hitting different solid surfaces (black, some with texture, some smooth). Contact angle is shown in gray.

6. ROBOSQUIDS AND JET PROPULSION

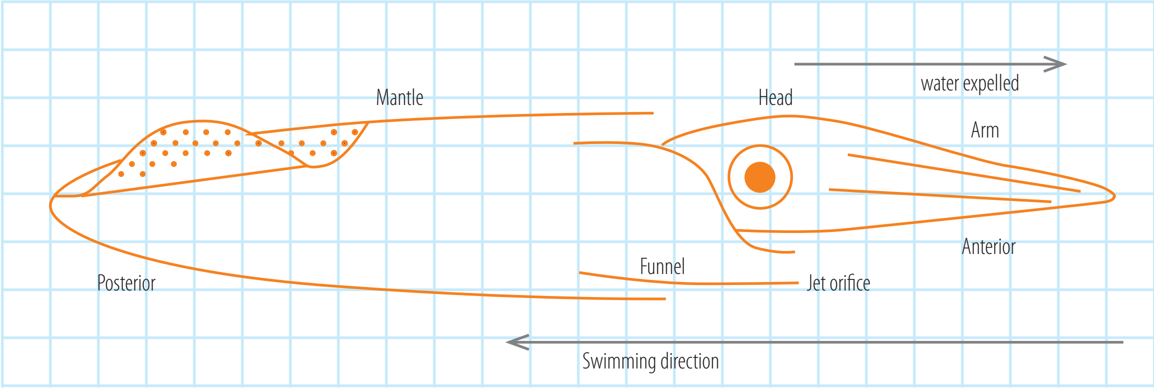
Some of God's most amazing designs are found underwater. The squid is one such creature. The elegance and speed at which they can move is captivating and visually hypnotic. Squids have jet engine-like capabilities that engineers would love to replicate. They are fast, effective, efficient, and quiet. Unfortunately, the soft tissue and moving parts of a squid have not made them easy to replicate. But we can study how they move to try to gain knowledge about what makes the squid so quick.

Squid movements resemble pulses, but a closer look reveals the secret behind the squid's propulsion cycle. The squid's head area emits a vortex ring that gives it amazing sprinting speeds of around 20 mph. Squids are torpedo-shaped and, curiously, their heads seem to be located in the back area where the vortex is expelled.

We see vortex rings in jet engines where we see a steady plume of exhaust trailing behind it. But the squid's vortex is a burst of fluid that exits a nozzle and expands in the shape of a donut and then curls back on itself. It resembles a plume, the shape of a donut ring, which gives it thrust and propels it forward.

The rearward-directed thrust that propels it forward is a principle called Newton's Third Law of Motion, which states "For every action, there is an equal and opposite reaction."

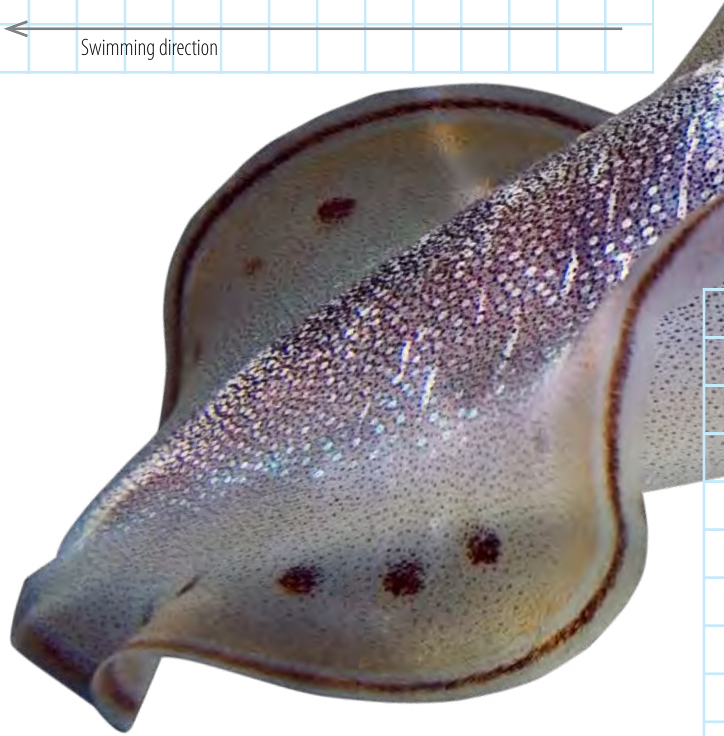
This is possible because the main body or mantle of a squid has a cavity that has two openings around its head — an inlet and outlet.



Inlet	the larger opening surrounding the head draws in water and fills the mantle cavity
Outlet	funnel-shaped, which almost looks like an exhaust pipe that expels fluid

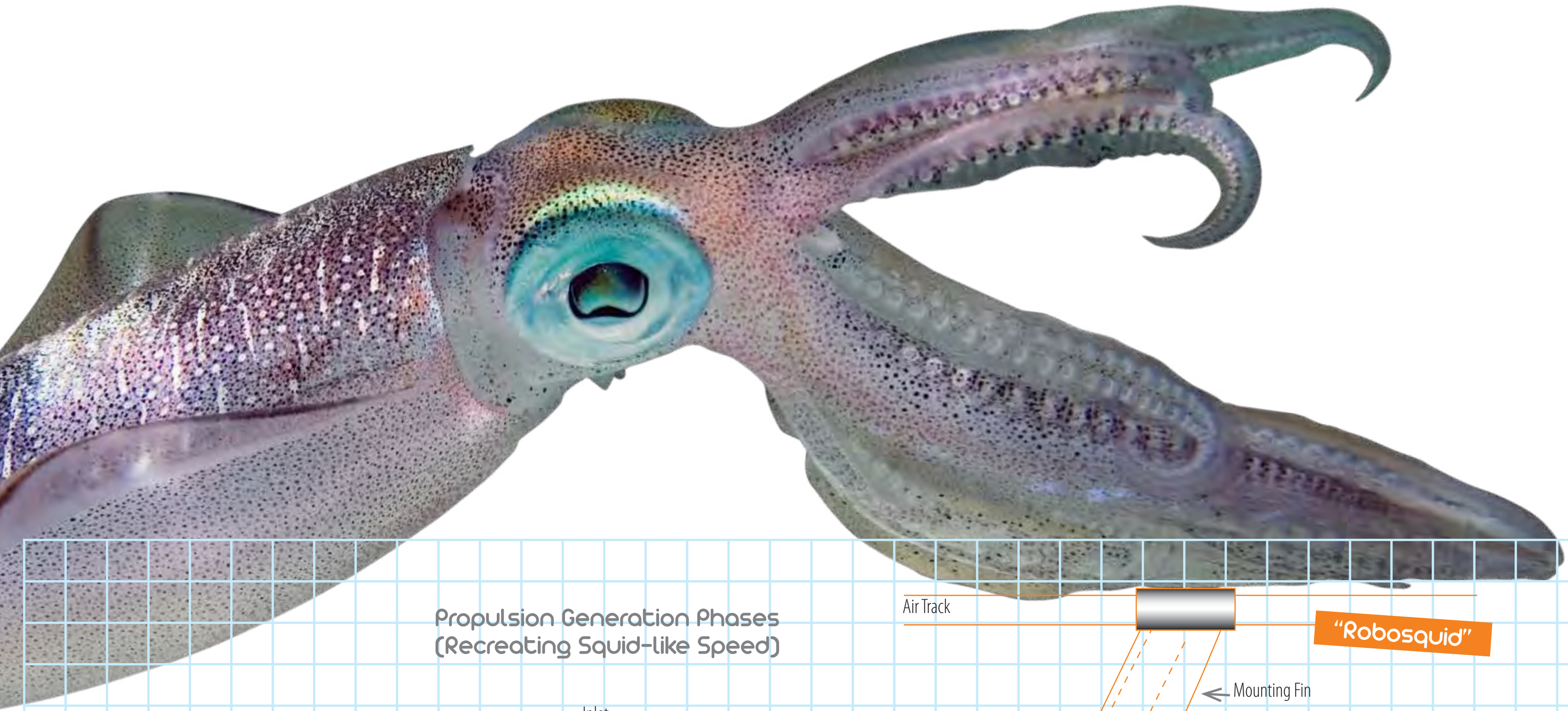
There are circular muscles surrounding the mantle that draw in and expel the fluid from its cavity. As the muscles of the mantle expand (open), the squid begins drawing water in from its inlet. Once the cavity has been filled, the inlet closes. The squid then begins to contract its muscles and expels (shoots) out the water through the smaller funnel opening. The funnel is how the squid is propelled at such high speeds and is similar to filling a balloon with air and then letting it go. The force of the air released forcefully shoots the balloon away from you at high speeds.

Southern Methodist University has developed a self-propelled pulsed jet vehicle rightly named "Robosquid." Their dissertation *Propulsive Efficiency of a Biomorphic Pulsed-jet Underwater Vehicle* is axiomatic. The Robosquid aims to construct an efficient, propulsive, underwater vehicle that uses an oscillating piston to generate the pulsed jets of thrust. Their observations could also contribute to those looking toward Nanobots that could be used to navigate through the thick fluids in the human body to diagnose disease.

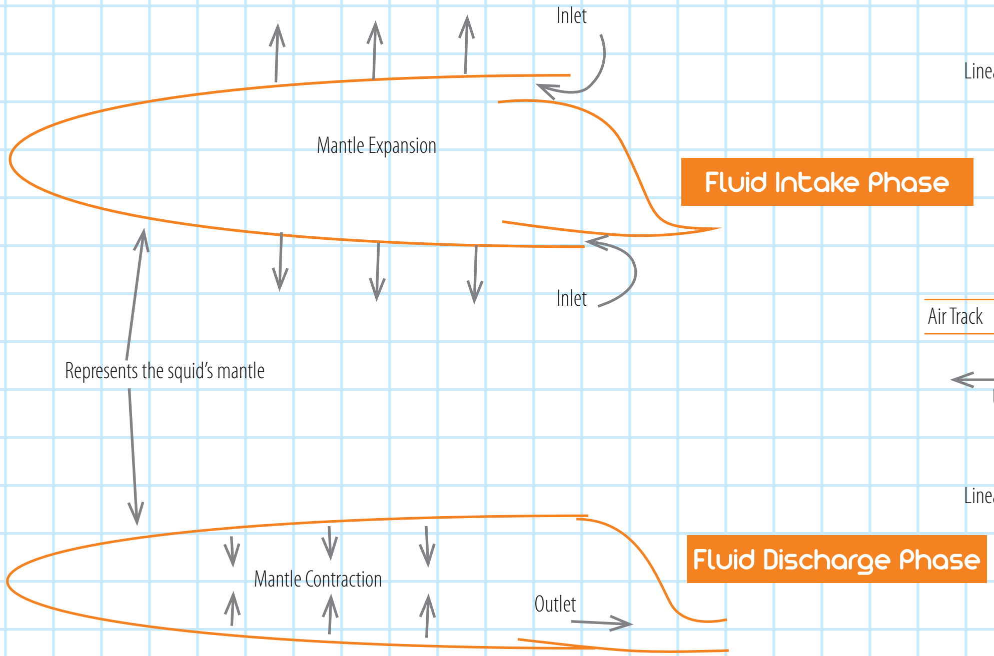


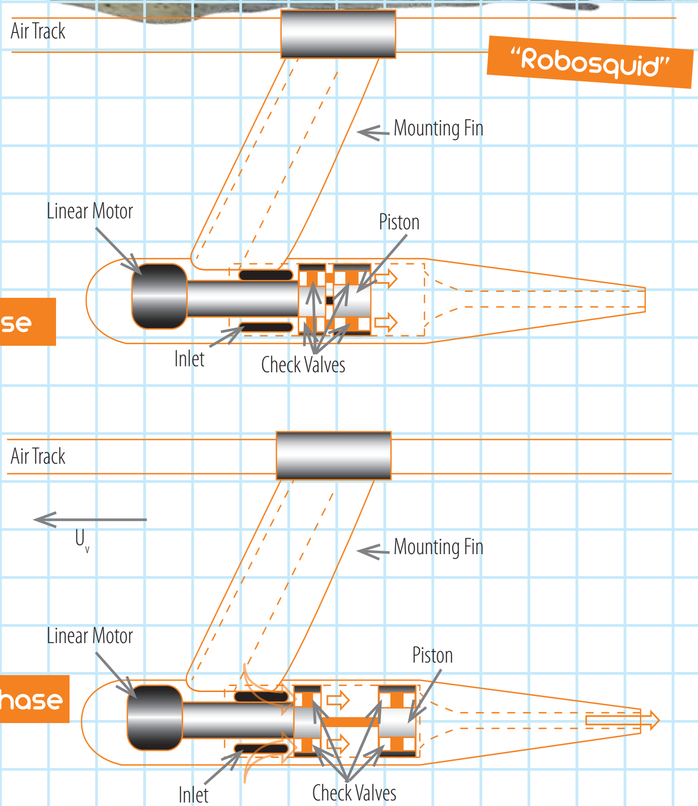
Technically, it has been challenging to those conducting these studies, but we would not expect any less from studying the complex and wonderful creations of God.

NOTE: This nanobot is not to scale. Proposed nanobots are tiny robots that go where others cannot. They vary in size and are typically measured by nanometers. Ten thousand nanometers is about the thickness of a human hair.



Propulsion Generation Phases (Recreating Squid-like Speed)





7. MANTIS SHRIMP EYE IMPROVES NEXT WAVE OF ENTERTAINMENT TECHNOLOGY

Technology seems like it's moving at the speed of light. Home entertainment technology has evolved beyond the VCR. What we see and hear matters when it comes to entertainment. We want our reds as red as they can be. We want yellows that make the sun look dim and blues that are bluer than the Pacific Ocean.

Scientists think they may hold the key to the next generation of visual technology after examining the sensitive eyes of a strangely captivating stomatopod known as the mantis shrimp. Biologists have labeled them "shrimp from Mars" because they are biological standouts. The mantis shrimp have intricately complicated eyes that can distinguish between 100,000 colors. That is an incredible ten (10) times more than humans, but their capabilities go beyond this. They can also see circular polarized light (CPL), an extraordinary ability that no other creature can claim.

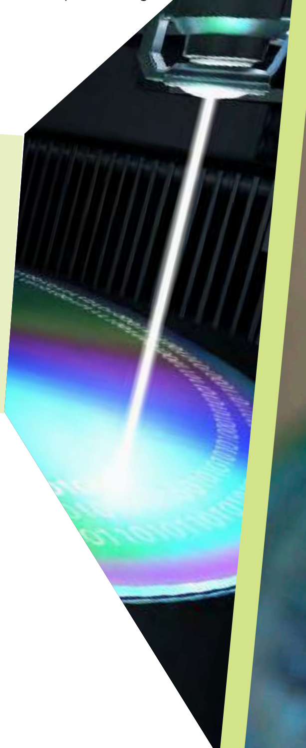
Polarization can be illustrated by the glare off another vehicle that you experience when you drive down a sunny road. That glare is the polarization of light after being reflected off the surface of another vehicle. When light hits a reflective surface it will bounce off and be projected onto a two-dimensional plane (flat surface) that is parallel to the reflecting surface.

That glare is the reflection that our eyes see as a blade of light and is known as linear polarization of light. Many sunglasses offer a polarized lens option that filters out polarized light, resulting in a crisp, glare-free image.

The polarization of interest to scientists is circular polarized light (CPL), where light goes through a conversion with a pattern similar to a corkscrew. Data transmitted as CPL allows greater data transmission and lends itself to a loss-free transmission.

Consumers are data-storage hungry. We want more to fit in to less. We want to squeeze more movies, pictures, and information into smaller storage units. It started with CDs and the technology is growing, albeit not at the breakneck speed of other technologies. The CD was first introduced in 1978, DVD in 1995, and Blu-Ray in 2006.

Biologists know the mantis shrimp's eye has the incredible capability of converting linear polarized light to CPLs and vice versa. Remember all those colors it could filter? Mantis shrimp eyes perform this conversion across the whole visible spectrum.



Mantis Shrimp eyes feature sensitivity related design.