Biomimicry Project

Biomimicry: Surgical Stability Inspired by Nature’s Wonders

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NASA CHALLENGES

Challenge:

The Viability of Robotic Surgeons in Deep Space Exploration

PERSISTENCE OF LIFE IN EXTREME ENVIRONMENTS

Society's advancements in space exploration throughout the years have improved drastically. Satellites and rovers have been sent to places far beyond the grasp our imagination, retrieving data from extraterrestrial bodies and environments that are vital to further progress in the different fields of spatial research. Rockets have been developed to overcome the Earth's gravitational field and launch into space. These rockets allow us send actual human beings beyond the Earth. Despite having medical training before launching into space, astronauts can still be put into detrimental situations if a major accident was to occur. This is because their medical training encompasses only common space adaptation problems. Without the presence of a fully trained surgeon on board, astronauts are burdened with the possibility of someone's appendage rupturing or some other form of major emergency occurring while on route in deep space. Thankfully, robotic surgeons are in place to aid astronauts in the event of an emergency.

NASA has tested the viability multiple robotic surgeons in space. The M7 is a telerobotic surgical system developed in 1998 with the goal of enabling surgeons to conduct operations from afar while maintaining the high level of precision of these intricate procedures. In plain terms, the M7 is basically two robotic arms, roughly the same size as a regular human's, that receive instructions from a surgeon and performs those instructions with a one second delay. Two tests have been conducted for the M7, one deep under the sea and another being high above the sky, and both tests have shown successful results. Essentially, NASA wanted to test the robotic surgeon in different types of extreme environments. The test underwater was conducted in the Aquarius Underwater Laboratory (60 ft. underwater). Other than testing the viability of the M7 over a far distance, the deep sea test examined the M7's ability to respond to the difference in pressure, as well as the presence of turbulence- which essentially showed that tremors are eliminated, as the M7 has software in it that compensates for the movements caused by turbulence.

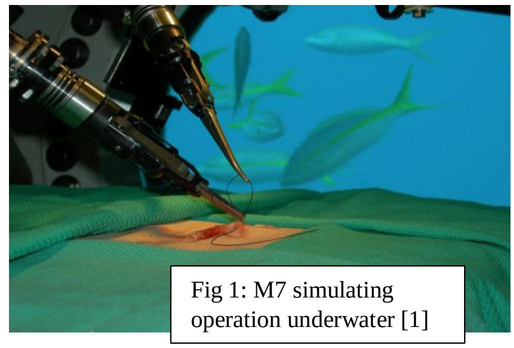

Fig 1: M7 simulating operation underwater [1]

The aerial test was a simulation for microgravity. Aircrafts were essentially moving at high speeds and in a parabolic nature to simulate transitions in gravitational forces.Short periods of weightlessness were created by the 45 degree angle made the aircraft, whilst the M7 conducted its surgery. After 60 parabolic flights, the amount of weightless periods was deemed enough to have an accurate representation of a deep space flight. Again, the M7 was shown to have compensated for sudden changes in movement and periods of weightlessness.

Fig 2:M7 using parabolic flights as a simulation for gravity [2]

In a way, the M7 can perform better in the deep sea and aerial scenarios better than actual surgeon. The M7 compensates for the sudden changes in movement, while a surgeon does not have some special software that would allow for that kind of response. As well, motion-sickness might be a factor on how well a surgeon would perform under

Similar to the M7, a surgical robot called RAVEN was also tested to perform invasive procedures in extreme conditions. The RAVEN functions similarly to M7, although it being designed to be significantly smaller. The RAVEN's size is currently being reduced in order to fit it into ISS' micro-gravity glove box, which would prevent any form of contamination

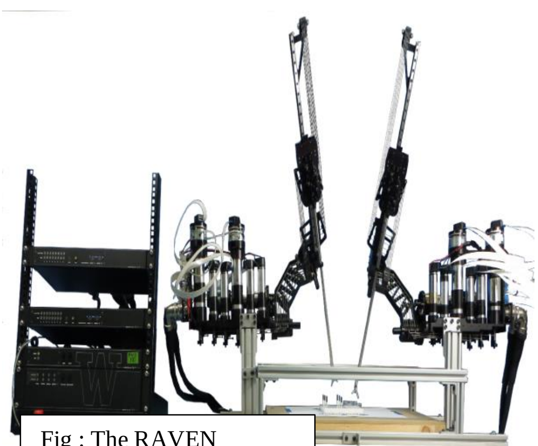

Fig : The RAVEN surgical robot [3]

Although these surgical arms have proven their viability in simulated conditions, their true capabilities have yet to be shown. Until the day testing occurs in actual space flights, the robotic arms will continue to have a layer of uncertainty attached to them in regards to how effective they truly are.

For instance, the amount of weightless periods generated by 60 parabolic flights during the aerial testing of the M7 is an assumption, albeit a calculated one. Assumptions can be dangerous, especially during life-and-death scenarios up in space. Adding up data from the short periods of weightlessness does not hold the same accuracy as using data from an actual long period of weightlessness or gravitational transitions.

The arms respond to sudden changes of movement while being in the Earth's gravitational field; however, the tests never portrayed how the arms will respond to these movements (or lack of) once gravity is removed from the situation. The stability of these arms while performing in deep space environments were never truly determined. Will the tremors remain absent in space? Will gravitational transitions act similarly to turbulence? Will the arms compensate the same way during these transitions? These questions will linger until the tests move from simulations to legitimate field testing.

Fig 4: A typical robotic surgical arm [4]

Despite these ambiguities, the arms can still be of use here on Earth. During emergency situations, in an ambulance per se, the arms can be used to perform on-the-spot incisions whilst the vehicle moves. The arms have proven their viability under the Earth's gravitational field. The movement of the vehicle will have no effect on how the arms operate, as the arms will compensate accordingly to correct the movement.

For now, research must be conducted and advancements must be met to "bridge the distance between earthbound medical support and astronauts."

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Challenge:
Growing Food in Deep Space

PERSISTENCE OF LIFE IN EXTREME ENVIRONMENTS

Food is one of our basic necessities. Humans are omnivores, with our diet consisting mainly of plants and meat. During space exploration, these necessities are not readily available. They have to be pre-packed and must either be carried during the launch or be sent afterwards.

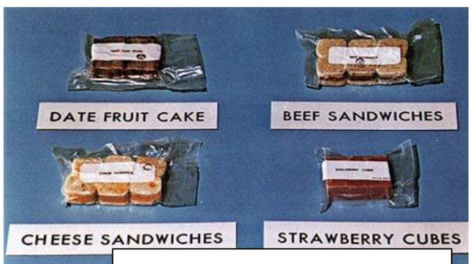

Fig 5: An astronaut's typical pre-packed food [5]

Astronauts' meals mostly consist of pouched and *ready-to-eat* meals or *just-add-water* meals. Having these types of food on a daily basis can get quite tiring, despite tasting the same as food on Earth. Astronauts have expressed that these space foods do not have the same feel as food on Earth. The tiresomeness that may arise from eating food in this mundane way can lead to a weaker physique. Astronauts may not intake the required amount of calories and nutrients needed to function effectively in space if they do not eat enough food. On top of that, a more mentally consequential result of this way of life would be the diminishing of morale.

An alternative to this way of receiving food would be to grow it in space. However, will plants grown in space be safe to eat and be easily manageable? This question is what NASA focuses on in their testing. Veg-01 and Veg-03 are tests that directly follow each other regarding the feasibility of growing food in space. Lettuce was the test-plant researchers grew in the ISS. The methods in which these plants are grown involve the use of a root mat and six "pillows." The pillows are essentially pod-like compartments that carry the seeds of the plants, the soil, the water, and the sensors that would detect fluctuations in the plants' properties (e.g. water intake, salt concentration). The plants are fertilized with calcined clay, similar to that found in baseball fields, allowing for an improved method of air circulation for the plant.

A simulation of the tests on the ISS was conducted on Earth. The same process will be applied to the simulation as was in the ISS. Periodical maintenance of the plants will be applied. These include watering them, thinning the pillows, and microbial testing.

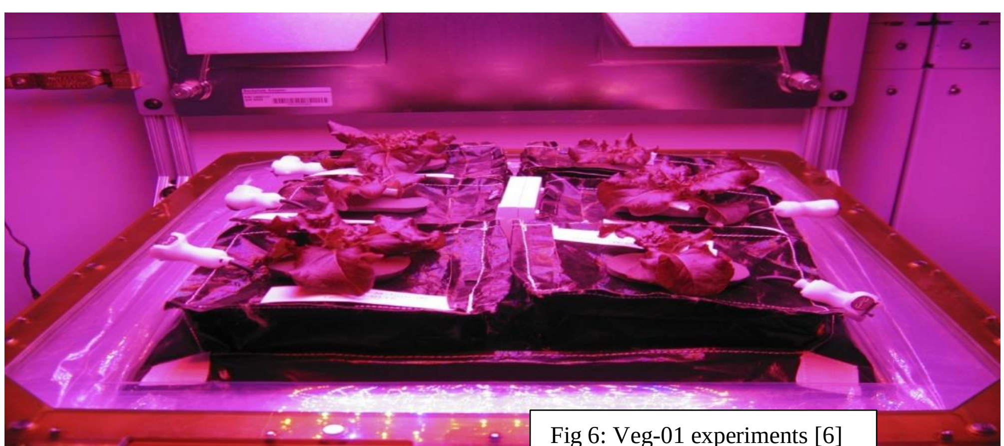

Fig 6: Veg-01 experiments [6]

Over the course of 28 days, photographs of the plant will be taken weekly to analyze its growth patterns. Once the cycle is over, the plants will be harvested and be sent to the SpaceX-4 mission. This simulation can act as a comparison for the tests done in the ISS. The deviations between the two experiments would allow researchers to pinpoint the effects the extreme conditions of space have on the lettuce plant. The original experiment in the ISS will remain in the ISS, acting as a sort of research platform for other plant-growing tests.

The experiment's goal is to create a way for astronauts to grow their own food in space through the use of these pillows. Several tests have already been conducted to refine and improve upon the pillow's effectiveness and ergonomics. They were designed to be modular, and easily maintained. Through these, researchers developed different types of pillows to accommodate different type of plants (e.g. Zinnia seeds).

Fig 7: The On-Earth control simulation of the Veg experiments [7]

The data acquired from the tests will determine the distribution of water and roots, aiding the future of these Veg tests. Anomalies in the plant's growth can also be analyzed from the plant samples by comparing it against the samples that were grown in the simulation. The comparisons will direct the researchers on the acceptable amount of microbial growth on the plants, impacting the safety of the food. In relation to microbial growth, due to the fact that the pillows are single use, the possibility of contamination due to microbes is reduced. However, despite a lower chance of contamination, sanitation methods are still required for certain types of plants that naturally have a high amount of microorganisms.

Veg-03 is an extension of Veg-01, functioning similarly in almost all aspects but one: scale. Veg-01 was conducted within the bounds of the ISS. The data collected from Veg-01 was mainly useful for controlled environments. Veg-03, on the other, will expand upon this. The Veg-03 tests are aimed to be a larger scale of growing plants, especially now that space exploration is hurtling towards Mars. Veg-03 will be using Tokyo Bekana Cabbage instead of Veg-01's lettuce and Zinnia seeds. The variety of the plant type being tested also improves the information being collected by providing variety. One type of plant's reaction to a given stimuli does not represent how the rest of the plant kingdom will react to the same stimuli.

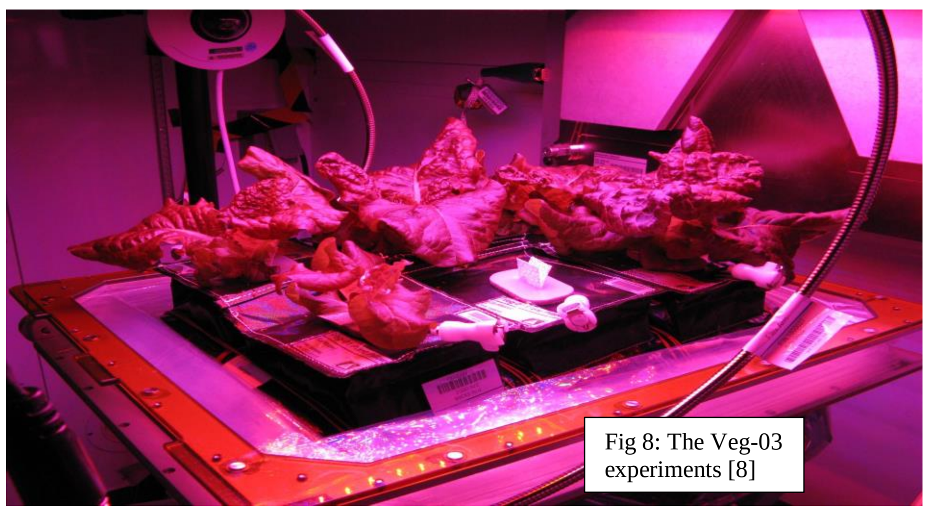

Fig 8: The Veg-03 experiments [8]

Through the help of these tests, we inch closer and closer to developing a more self-sustained food production system for space explorations.

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Challenge:
Creating Durable and Flexible Space Gloves

MATERIALS FOR EXTREME ENVIRONMENT

Space suits provide protection for astronauts from the harshness of the environment in space, such as radiation and low temperatures. The suits have specially designed materials that prevent astronauts from being harmed by the different electromagnetic waves that are present in space, with Ultraviolet rays being a prominent one. Fingers are one of the human body part's that easily gets cold. In the freezing temperatures of space, the suit's gloves are essential for astronauts to survive and do their task. With heaters in the glove's fingertips, the thermal properties of the gloves (as well as the suit) can be controlled. The gloves also allow the astronaut to pick up objects, which is accomplished through the help of a bearing that allows the wrist to be more mobile. Despite these properties, however, NASA's space gloves have been facing problems recently.

The durability of astronauts' space gloves is currently posing a concern. They have been wearing down, with holes and tears forming on the outer side of the glove. The index finger and thumb portions of the glove tend to be the areas where damage is most likely to occur. Although, the gloves still protect the astronaut's hand from the environment in space, the protective properties of the gloves decrease as more damage wears them down.

Fig 9: Space gloves being damaged [9]

NASA attempts to combat this issue by using what they already have, however with slight modifications. Vectran is the protective material that the glove is composed on. NASA improved upon this design by tightening the weave of the material in the patches, especially in the areas of highly probable damage.

Fig 10: Patches applied to aid the durabiltiy of gloves

As mentioned earlier, the damage on the gloves are not currently posing a life-and-death situation for the astronauts. Gloves are composed of several layers: a bladder, a restraint, and a TMG palm. Only the top protective layer of the gloves (TMG Palm) has been damaged. This does not pose as much of a threat to the safety of the astronauts compared to damage being done to the inner layers. However, with the outer layer damaged, the inner layers are more susceptible to being worn down. Compared to the outer layer, the inner layers are more important as it allows the suit to be constantly pressurized.

Fig 11: The Components of a Space Glove [11]

Besides the wearing down of the glove's outer surface, another issue plagues the inner layers of the gloves. The gloves' flexibility is sacrificed to allow for its protective functionality. These space gloves are often tight, resulting to the restriction of blood flow in the fingers. This then leads to the pressure sustaining at the fingertips, which cause finger nails to break. In extreme cases, however, the fingernails can eventually detach themselves from the fingers. On top of this, moisture formed within the gloves may cause bacteria to grow in the wounds inflicted by the gloves' tight fit.

Researchers compiled data from 232 astronauts to determine if the fingernail issues are isolated cases or are more common than not. They found that 10% of the astronauts experienced some form of trauma on their fingernails, as a result of the tight space gloves. They analyzed 22 hand measurements, and from these measurements, they found that injury rates are more common for astronauts whose hands are larger than 9 inches. They also found that the glove most restricts the metacarpal joints of the hand, which are joins that allow our fingers to bend over our palm. This issue arises from the design of the glove. A bar is located in the fabric of the glove that would allow the fingers to bend over the palm. However, the bar also puts pressure onto the joints, which restrict movement and blood flow.

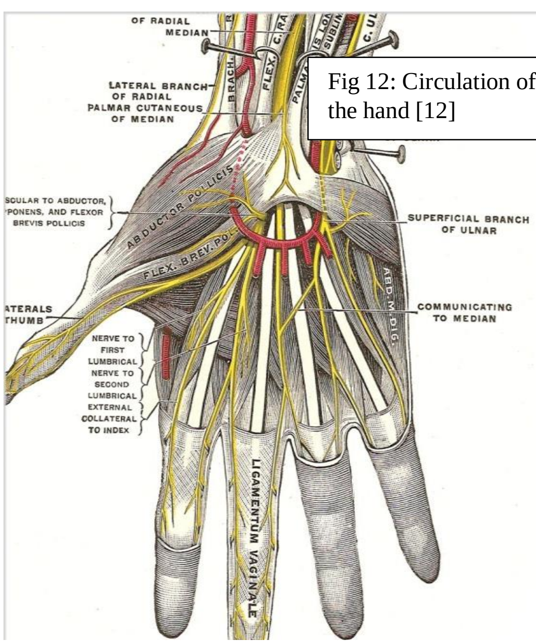

Fig 12: Circulation of the hand [12]

By repeatedly putting on and taking off the gloves, the circulation of blood flow along the joints and the fingers is in a constant state of flux. This causes damage on the tissue under the fingernail. This damage also explains some astronauts' complaints of having cold finger tips, despite having a heater within the gloves.

Solutions to this issue are currently being discussed. One of the proposed solutions involves the use of robotic amplifications within the gloves. The inner layers are gas-pressurized, which would mean that any movement made by the astronaut would have to overcome the pressure of the glove. Doing so leads to damaging the astronaut's hand and fingers. An alternative to this would be having a robotic actuator within the gloves that would lessen the amount of force required to overcome the pressure. This creates less pressure on the hands, less work to move, and allows for more circulation in the hands. However, this idea would not be feasible due to the size these actuators need to be. The actuators need to small enough to fit in the glove, and have ample space left for a hand to fit in. However, if an actuar of this nature was to be made, it would be roughly the size of a hand, given an exoskeleton-esque form.

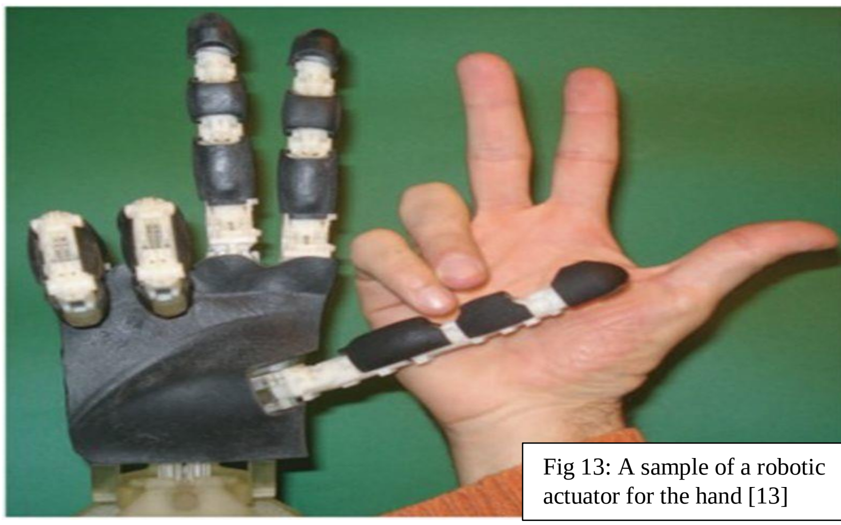
Fig 13: A sample of a robotic actuator for the hand [13]

These gloves create a trade-off between dexterity and strength. The nature of the vacuum in space compromises the gloves' strength, whilst the gloves' strength compromises their ability to be flexible. The natural movement of the astronauts are hindered by the need for protection. For now, advancements must be made to meet the need for a protective glove that does not sacrifice its durability for motion.

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Nature's Solutions

BOXFISH

Function:

Retain stability during sudden motion changes.

Mechanism:

Creating a difference in pressure through vortices of water

Ostracion Cubicus

Biological Strategy

As the name of the organism implies, the yellow box fish is a fish whose body is shaped into a box like structure. These creatures are models of hydrodynamic efficiency due to their special ability: **remaining stable in turbulent waters.**

Turbulent water does not faze these box shaped organisms. Originally, researchers thought that the shape of the fish alone created less drag, and therefore allowed the fish to move efficiently in turbulent waters. However, the box shape of the fish is not the true source of the boxfish's stabilizing ability. Rather, stability lies in the keels of the boxfish's box-like structure. **Spiral vortices of water** form along the keels of the boxfish, allowing for stability in areas where needed. The keels utilize the turbulent water to create these vortices. The sides of the boxfish are lined with specially grooved scales and bumps that aid the keels in transporting water around it, forming the vortices that stabilize the boxfish.

The boxfish uses a lever-like mechanism with its vortices. Imagine a see-saw: if weight is added to one side and not the other, the weightless side would rise. However, if the weightless side is pulled by some force equal to the weight of the other side, then the see-saw would rest at perfectly horizontal position.

F_g = Force of Gravity (N)
F_t = Force of Tension(N)

where, $F_g = F_t$ in magnitude

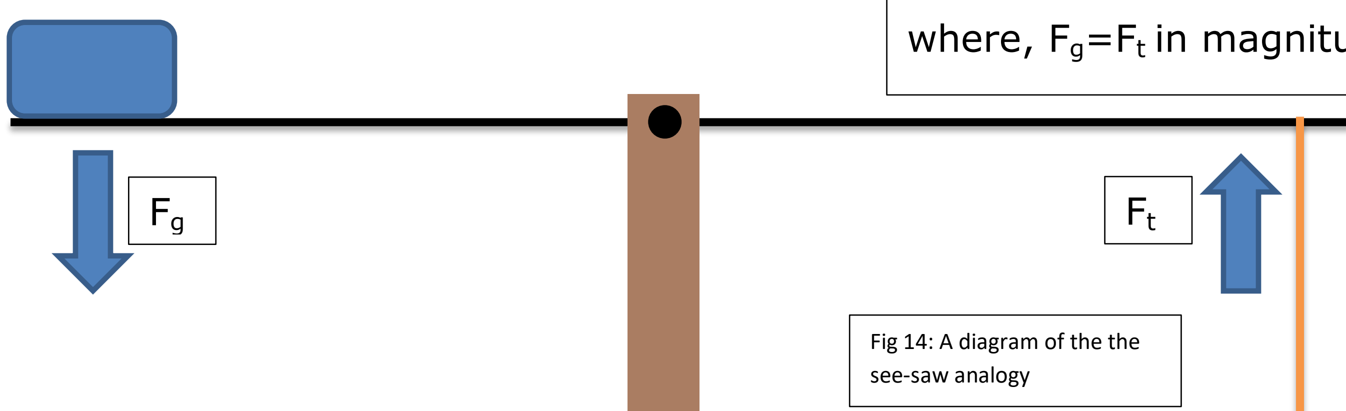


Fig 14: A diagram of the the see-saw analogy

This idea is translated into the use of pressure differences in the world of a boxfish. Let's say water pushes from above on the front part of a boxfish. The boxfish will then respond by whipping up a vortex of water from its underside at the back end of the boxfish, which is the complete opposite of side of where the water is hitting it. The vortex essentially flows along the keels and "touches" the surface of the boxfish. The vortex then creates a difference in pressure along it. **The pressure in the vortex is lower than the water pressure around, which essentially causes the boxfish to be pulled towards the vortex.** The vortex's pulling property counteracts the downward force of the turbulent water on the opposite side, thereby allowing the boxfish to remain stable.

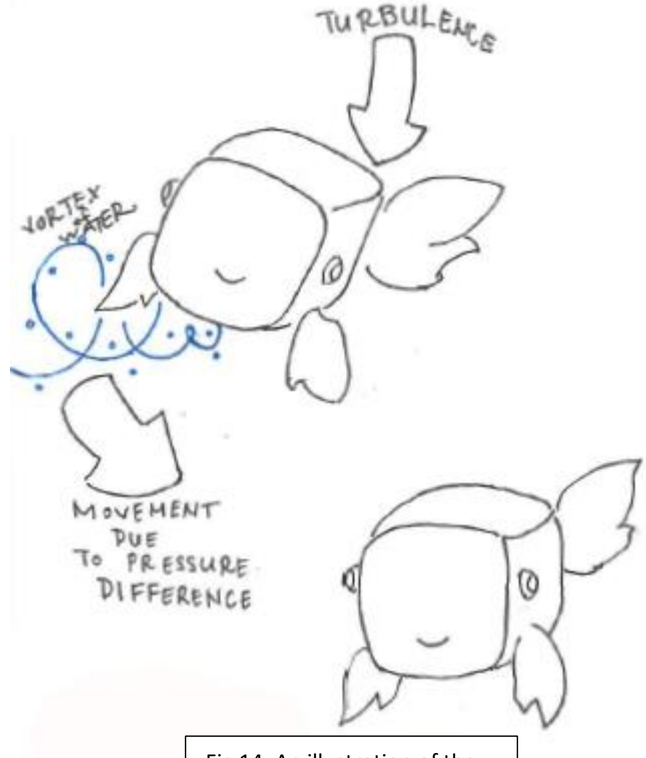
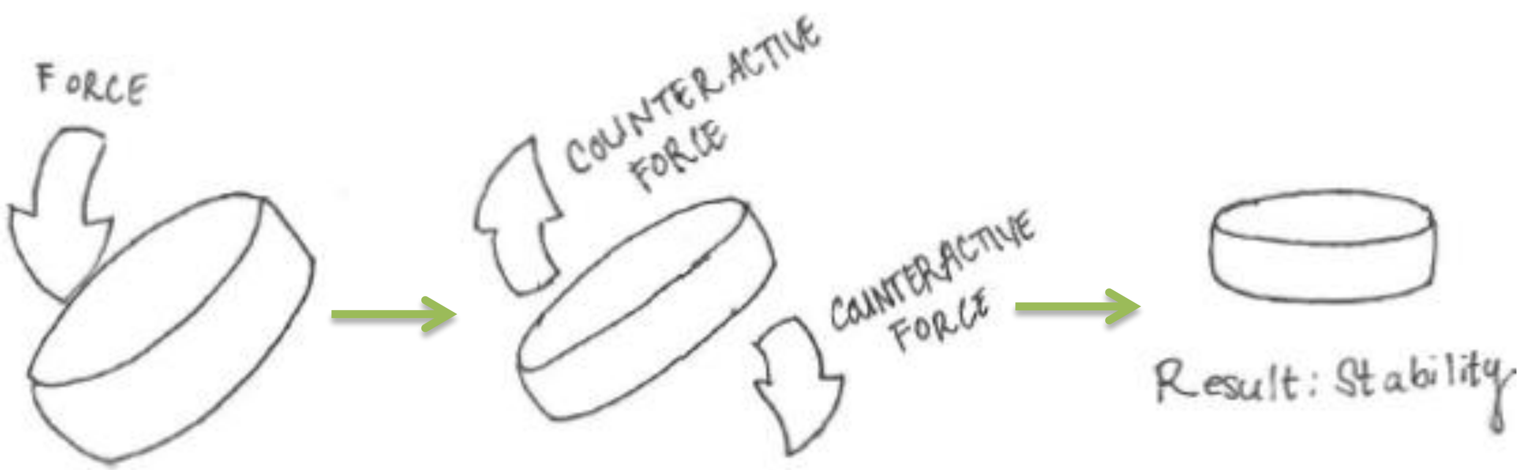


Fig 14: An illustration of the vortex's mechanism

Design Principle

A mechanism that would counteract different types of destabilizing forces to maintain stability



Application Ideas

- Apply mechanism onto tasks that require meticulous amount of care that may be influenced by sudden movement
- Can be applied onto buildings to prevent collapse by providing stability

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STRANGLER FIG

Ficus Citrifolia

Function:

Allocation of resources

Mechanism:

Parasitism through the use of roots

Biological Strategy

The appearance of strangler figs resembles a bizarre conglomerate of different types of trees. The tree's vines and roots sprout in all directions, whilst its trunk showcases a layered appearance. The odd and eerie appearance of these trees is a direct result of their adaptation for survival.

The seeds of these strangler trees begin off by attaching themselves on the branches of a host tree. Being a hemiepiphyte, a plant that spends a portion of its life in the air, the strangler's growth originally begins as an aerial plant. Overtime, roots will sprout from the growing tree and make its way to the ground. The roots search for an ideal area to lodge themselves into, posing a competition against the host tree. Overtime, the strangler tree's **roots will graft together wrap around the host tree**, essentially killing its host. The host's bark and phloem layers will be crushed by the strangler's engulfing roots and vines, which envelopes the original tree. The host tree will then have to compete against the strangler fig for resources such as root placements and accumulation of sunlight, leading to the host tree's death.

The strangler tree also has the capability **to create a network of strangler trees**. Instead of the roots engulfing the host tree, they would shoot into the ground permanently. The roots will thicken overtime and act as additional trunks where other strangler trees will grow from. This mechanism can interconnect patches and patches of fig trees, whilst consisting only of a single plant.

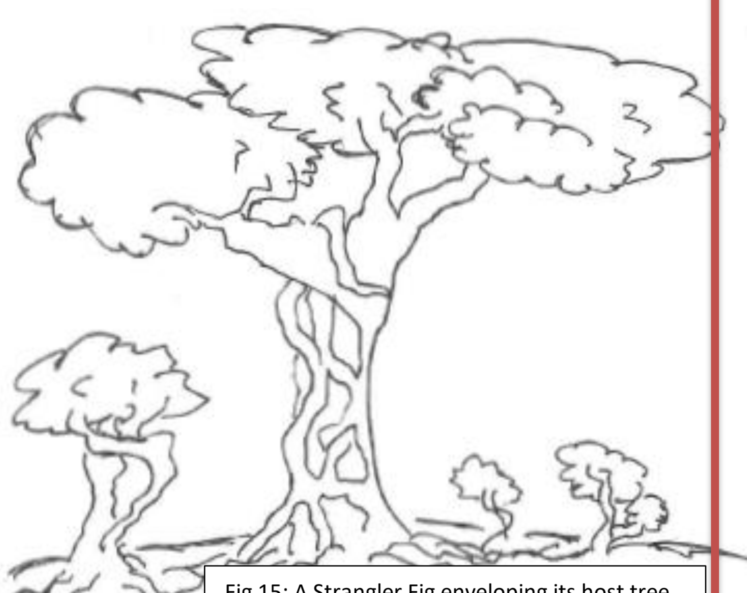


Fig 15: A Strangler Fig enveloping its host tree and creating a "network"

Strangler trees also have a notorious reputation of damaging infrastructure. The trees' roots will make its way through small crevices which will overtime be overwhelmed by the growth of the tree. Walls, for example, often end up being damaged by the strangler trees. Crevices in the wall turn into permanent damages once the strangler tree's roots pass through them.

The roots of the strangler tree are its main weapon of survival. Through the use of their roots, strangler trees search for where they can properly thrive in. The roots will plumage through concrete in search of soil, envelop living trees to fully grow, and have the capability to create networks of trees. The adaptive nature of the strangler trees allowed them to assess the possibility of life in different areas; and if life is not feasible, they changed the environmental makeup of the area to compensate.

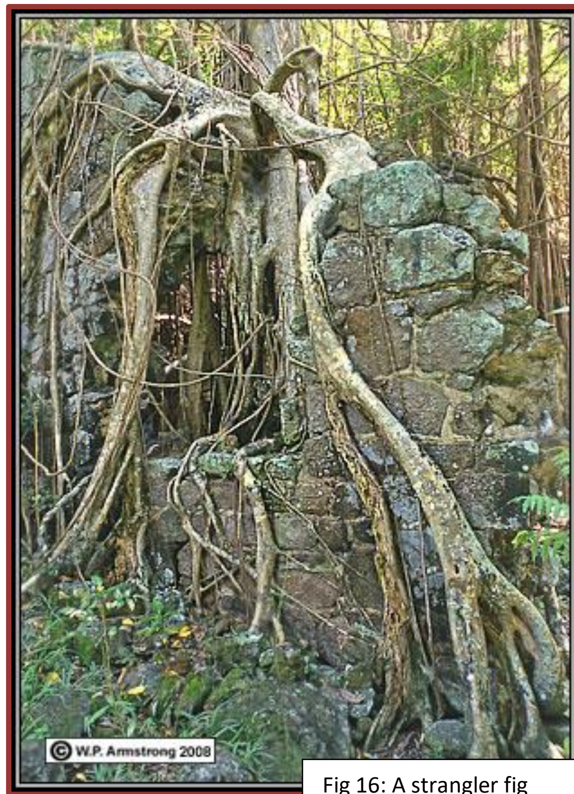
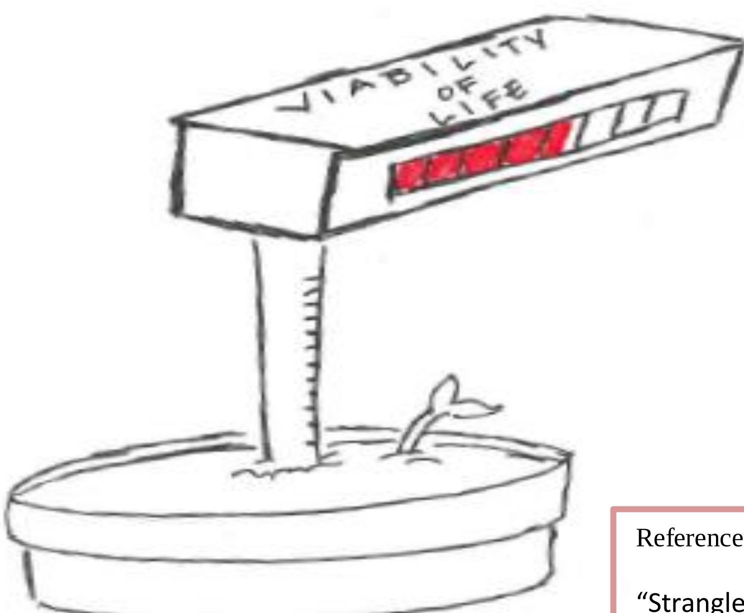


Fig 16: A strangler fig damaging a wall [14]

Design Principle

A mechanism that assesses the viability of growth in a given environment



Application Ideas

- Mechanism can be applied to test the safety of growing food in certain environments

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TARDIGRADE

Function:

Survive in extreme environments

Mechanism:

Cessation of metabolic processes

Tardigrada

Biological Strategy

Tardigrades are micro-invertebrates that grow up to 1 mm in length. The microscopic creatures look like they belong in another planet. The tardigrade's unique appearance is matched only by its unique ability: pseudo-immortality. Tardigrades can survive the harshest types of environments and situations. They can survive up to 10 years without food or water. They can survive through extreme temperatures, ranging from nearly absolute zero to well above water's boiling point. They can survive the lack of oxygen in space, the low pressures of vacuums, high pressures 6 times greater than that of the ocean depths, and even doses of radiation 1000 times greater than what humans can tolerate. So how do these microorganisms do it?

The tardigrade's pseudo-immortality can be attributed to its metabolic strategy: **cryptobiosis**. Cryptobiosis is a state in which an organism's **metabolic process is reduced to a bare minimum**. While most animals die with the cessation of their metabolic process, the tardigrade utilizes this cryptobiotic process to survive harsh conditions. Tardigrades undergo five main branches of metabolic cessation, each for a different type of extreme condition.

Anhydrobiosis for lack of water.
Cryobiosis for low temperatures.
Osmobiosis for changes in water salinity.
Anoxybiosis for the lack of oxygen.
Chemobiosis for high levels of toxins.

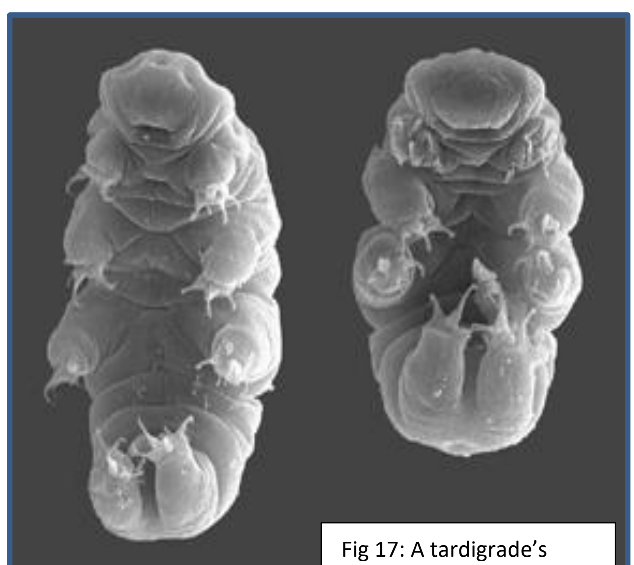


Fig 17: A tardigrade's normal form vs it's tun form [15]

The most common type of cryptobiosis the tardigrade exhibits in anhydrobiosis. In areas where the tardigarde cannot readily hydrate itself, it exhibits anhydrobiosis by curling up into a ball, reducing its metabolic processes to as low as 0.01% of its normal metabolism. This curled formation is called a tun. When the tardigrade curls into a tun, its metabolic processes are essentially undetectable.

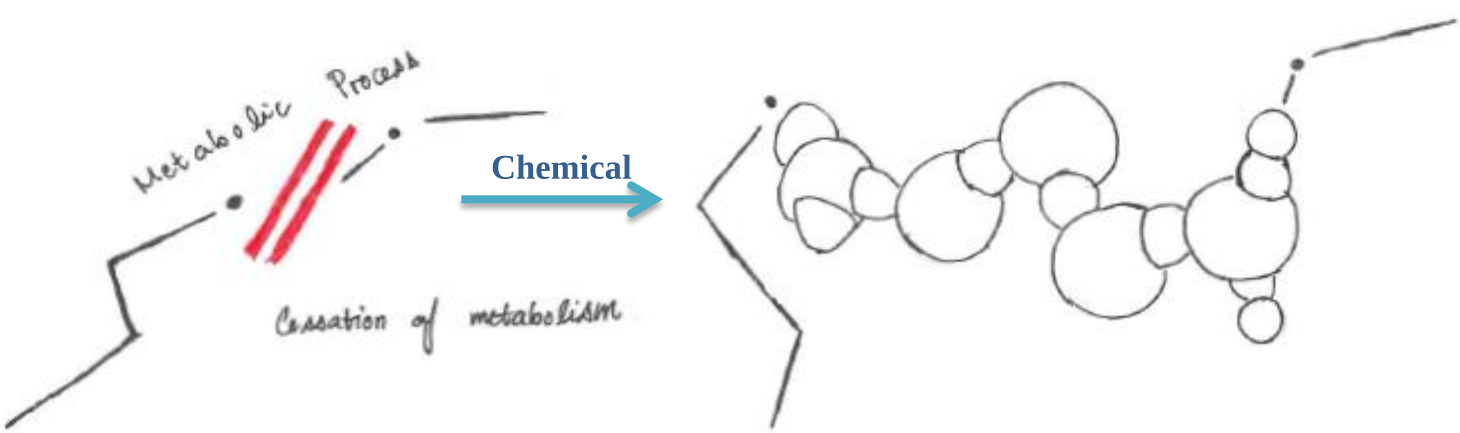
Trehalose is a protective sugar that moves into cells where water would normally move in, allowing the tardigrade to live through dehydration. The trehalose is not a stand-in for water, however. The compensation it provides is more so a protection or preservation of the tardigrade's cells. The trehalose is formed by a gel-like substance which suspends and preserves the cells of the tardigrade.

For environments that require the tardigrade to respond anoxybiotically, the tardigrade is capable of different techniques of survival. If the tardigrade was in a body of water that has a low makeup of oxygen, it stretches out into a long and relaxed state where its metabolic processes are reduced to a minimum. The relaxed state allows as much water and oxygen to enter its system as possible. In extremely cold temperatures, ice could form on the tardigrades body, harming its cells. To counter this, the tardigrade's tun forms cold-resistant molecules that hinder ice from forming on the tardigrade.

Currently, the tardigrade's ability to survive fatal amounts of radiation remains unclear. Studies are being made to uncover how the tardigrade protects itself from harsh levels of radiation. Tardigrades have survived a 10-day space flight after being exposed to 7577 kJ/m^2 of ultraviolet radiation. This level of radiation damages the DNA of organisms, leading to the formation of thymine dimers (CPDs) in the organism's DNA. CPDs cause mutation, and damage the DNA. The tardigrade's tolerance to this level of radiation led researches to hypothesize a form of DNA reparation in the tardigrades. Research has shown that CPDS were found in the tardigrade's cells; however, DNA repair activities were also detected in response to the formation of the harmful CPDs. This reparation is hypothesized to be dependent on light, as reparation was more apparent under the illumination of fluorescent light.

Design Principle

A chemical that allows other organisms to live through and undergo a state of minimal metabolic processes.



Application Ideas

- Apply chemical onto organisms that are going extinct to prolong life

- Apply chemical onto organisms necessary for survival in extreme environments (e.g. plants for growing)
  *however, this chemical cannot influence the safety of consuming these plants

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CHITON

Polyplacophora

Function:

Resisting damage under stress

Mechanism:

Using organically synthesized minerals for strength

Biological Strategy

The chiton is infamous for having one of the hardest teeth of any animal. Their teeth exhibit hardness three times more than the human enamel. Chitons are able to achieve this feat by creating their own hardening mineral: **magnetite**.

Magnetite is an iron-oxide mineral that coats the teeth of the chiton. The mineral's properties aid the chiton with scraping the sea floor for rock-embedded algae. Proteins and sugars found within the teeth create the magnetite. Fibres create a carbhohydrate scaffold that exhibit a criss-cross pattern, which bind the metallic ions (e.g. sodium). These ions are hypothesized to bind with proteins with negative charges, accumulating iron in the process, paving way for the iron-oxide mineral to form. As the ions bind with the scaffold, leading to iron-collection, bonds become stronger and the chiton's teeth become more and more structurally firm. The magnetite's properties in combination with flexible fibres allow the chiton's teeth to resist different types of stresses. The magnetite provides **wear-resistance**, whilst proteins, ions, and carbohydrates form the fibres that create **crack resistance**.

The organic and inorganic composition of the chiton's teeth is formed through an irregular **honeycomb pattern**, which envelope the magnetite material. It is hypothesized that the microscopic structure of the teeth aid the magnetite's hardening properties. This hypothesis is further backed by the structure's layers of fibrous material, which works in conjunction with the magnetite with the help of metal ions.

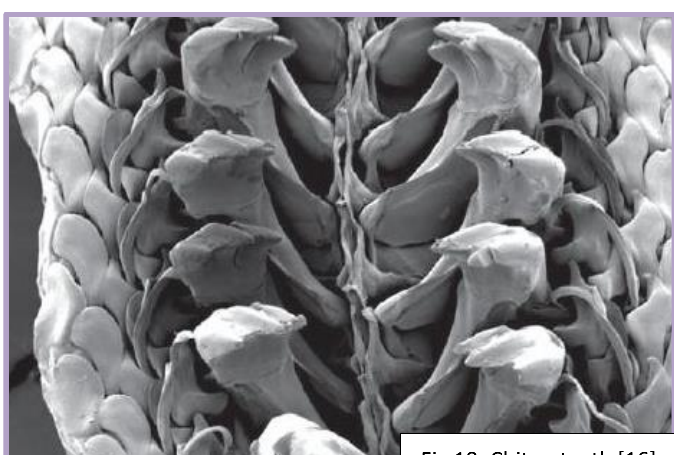


Fig 18: Chiton teeth [16]

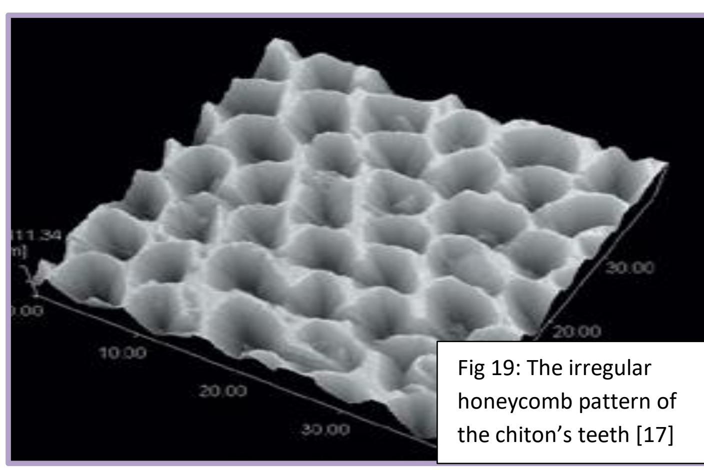
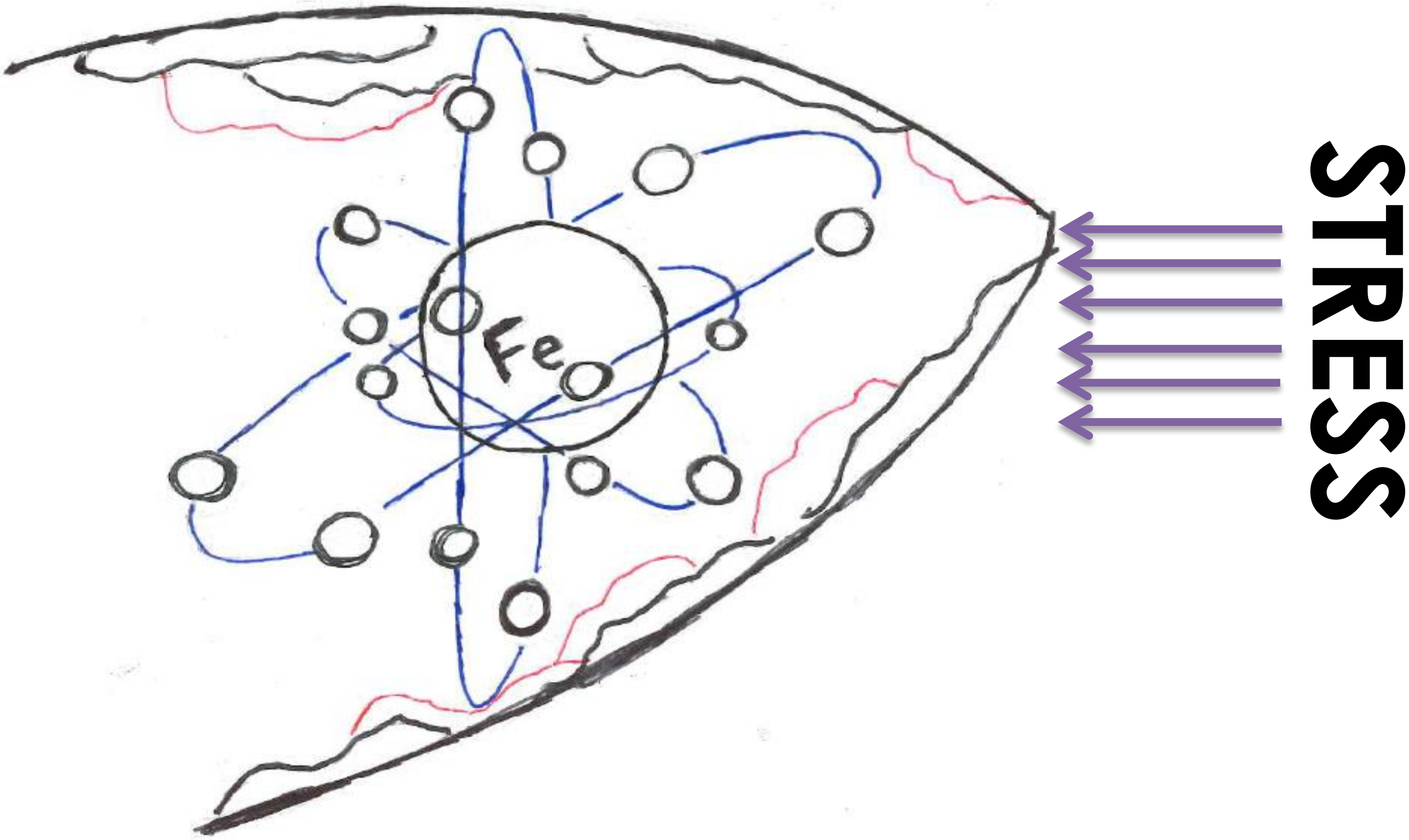


Fig 19: The irregular honeycomb pattern of the chiton's teeth [17]

Design Principle

A material composed of inorganic and organic substances (proteins, carbohydrates, iron, magnetite) to increase durability when stresses are applied.



Application Ideas

- This type of material can be applied onto construction to prevent different types of damage
- For extreme environments, the properties of this type of material can reduce the wear-and-tear equipment in these types of environments.

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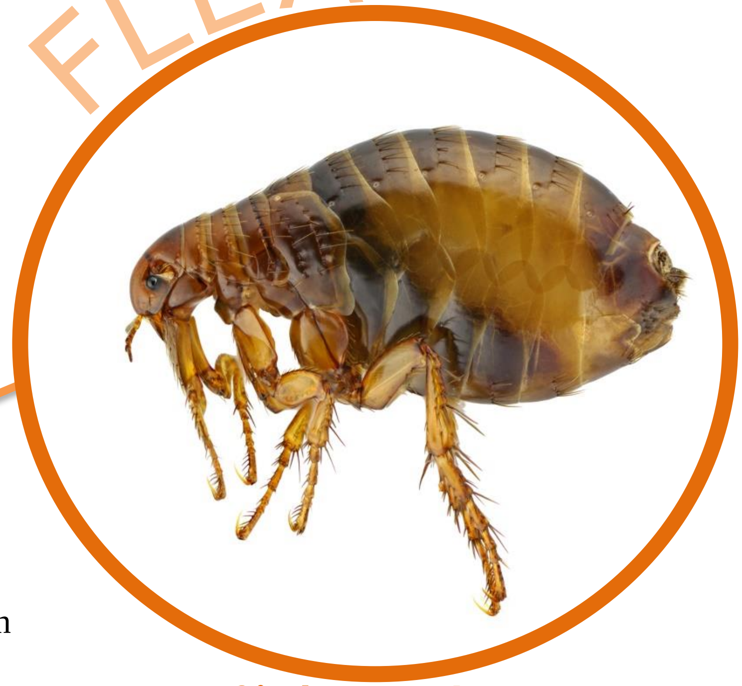
FLEA

Function:

Deforms and regains shape easily

Mechanism:

Elasticity of resilin allows it to stretch and regain its original form, allowing for the storage and release of energy



Siphonaptera

Biological Strategy

Fleas are infamous for being pests that cause skin irritation. Behind their notorious reputation lies an adaptation akin to a feat of Olympic proportions: their ability to jump 200 times their own body length. Like most parasitic insects, the flea lost its wings throughout its evolution. Despite this, however, it retained aspects of its previous flight mechanism to aid its jumping capabilities.

Winged insects like dragonflies have an elastic protein called **resilin** that help them manoeuvre their wings by absorbing compression and tension. The same protein can be found in the joints that connects a flea's legs to its body. When the resilin is **compressed, it stores the energy** of the compression until the point that it is released for a leap. Essentially, when a flea crouches to jump, the resilin found within its tendons compress and is held in this position through a series of muscles. Once the flea relaxes its muscles, the energy stored in the resilin transfers to the flea's legs. This energy transfer pushes the flea's legs onto the ground, allowing it to jump great heights relative to its size.

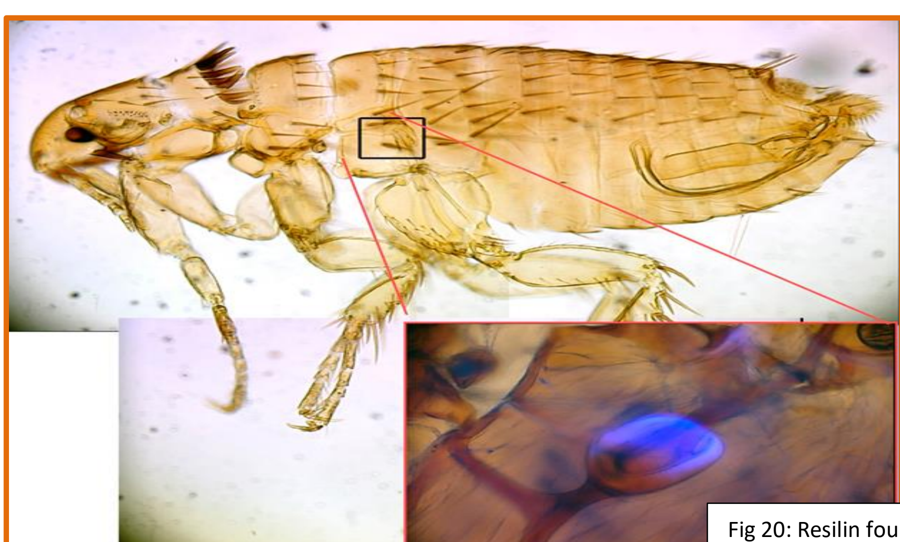
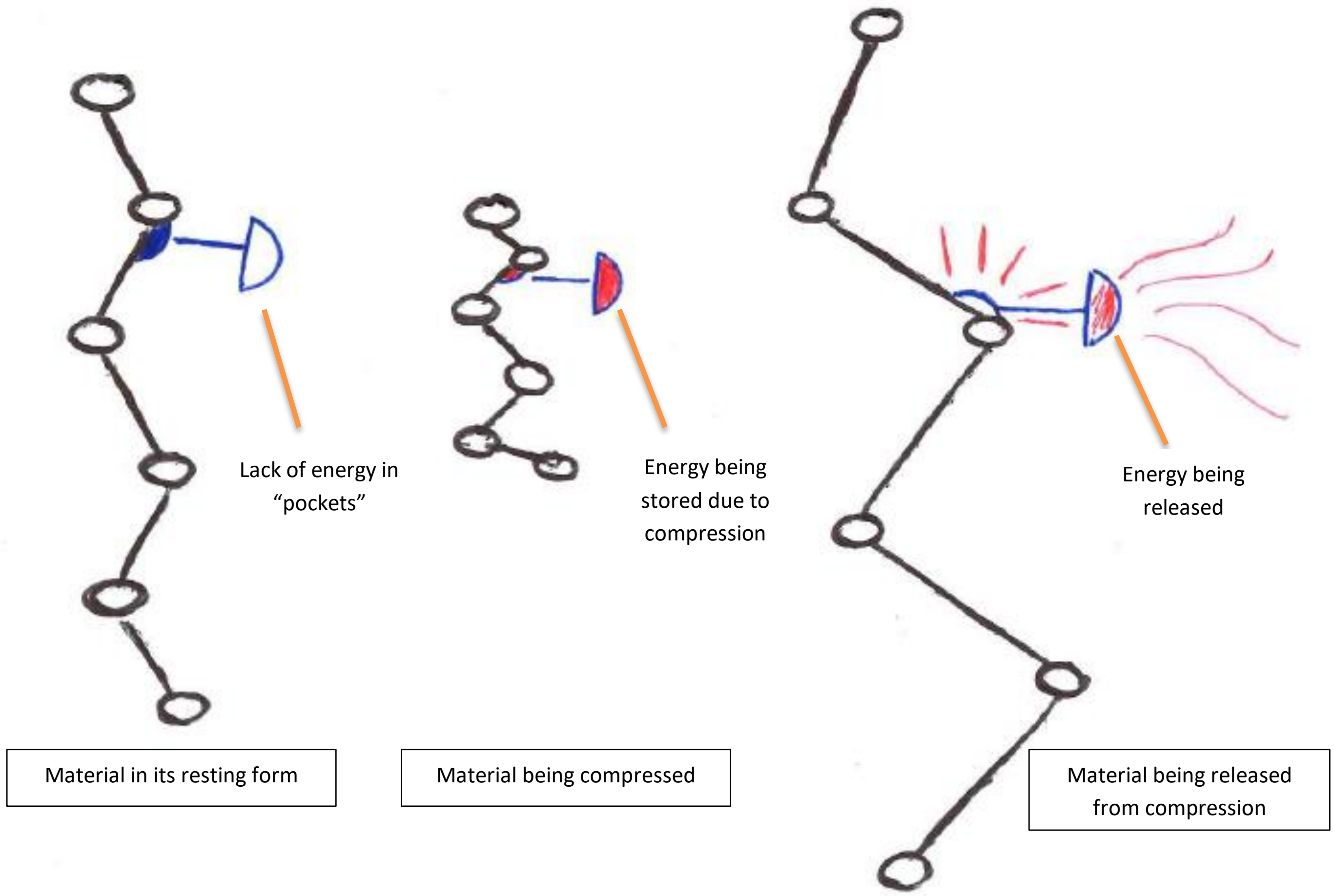


Fig 20: Resilin found in the joints of a flea's legs [18]

Design Principle

An elastic material that stores energy when compressed, and releases the energy once released.



Application Ideas

- The material can be used to increase movement in motion-related clothing
- The energy-mechanism of the material can be utilized as a form of thermoregulation

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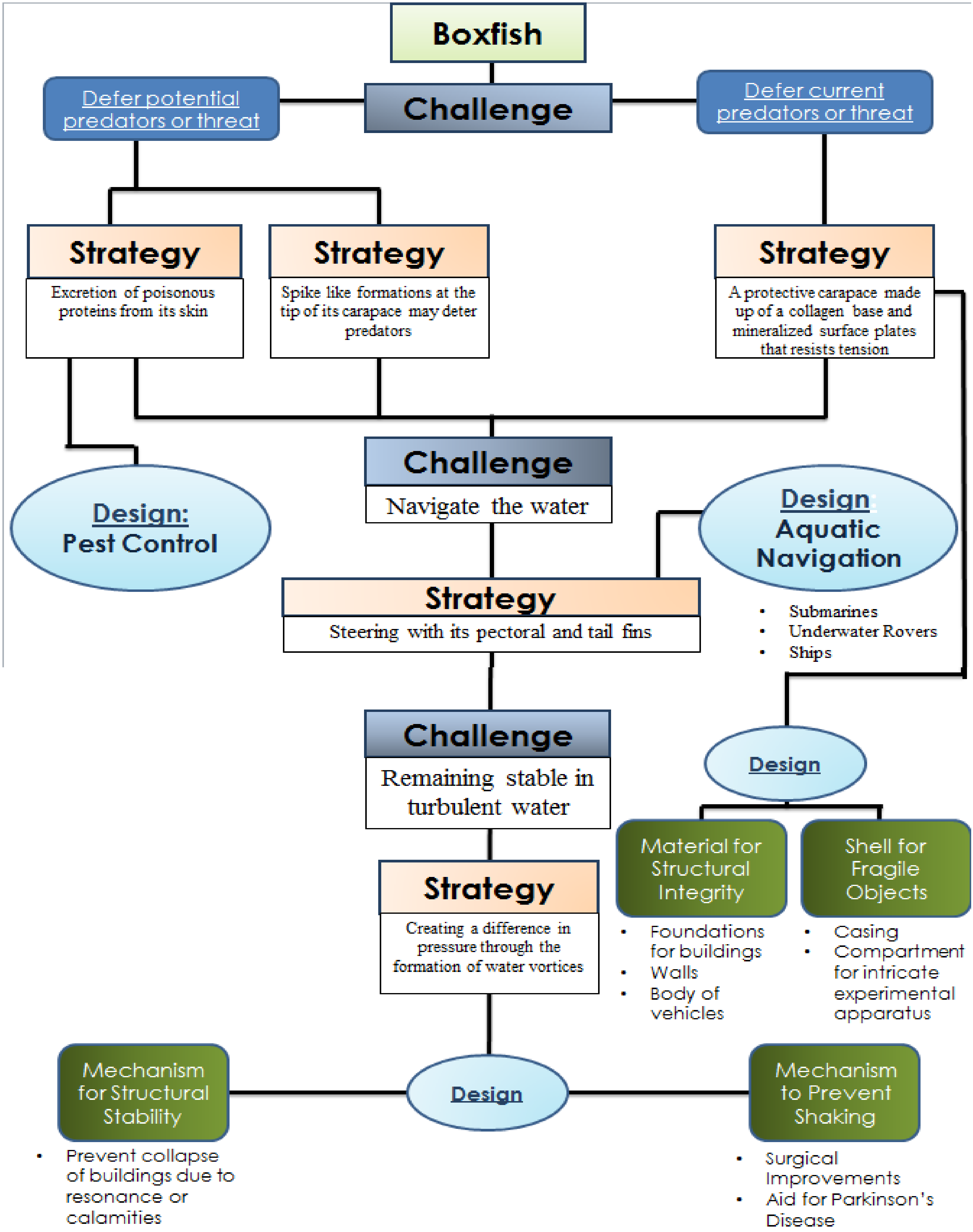
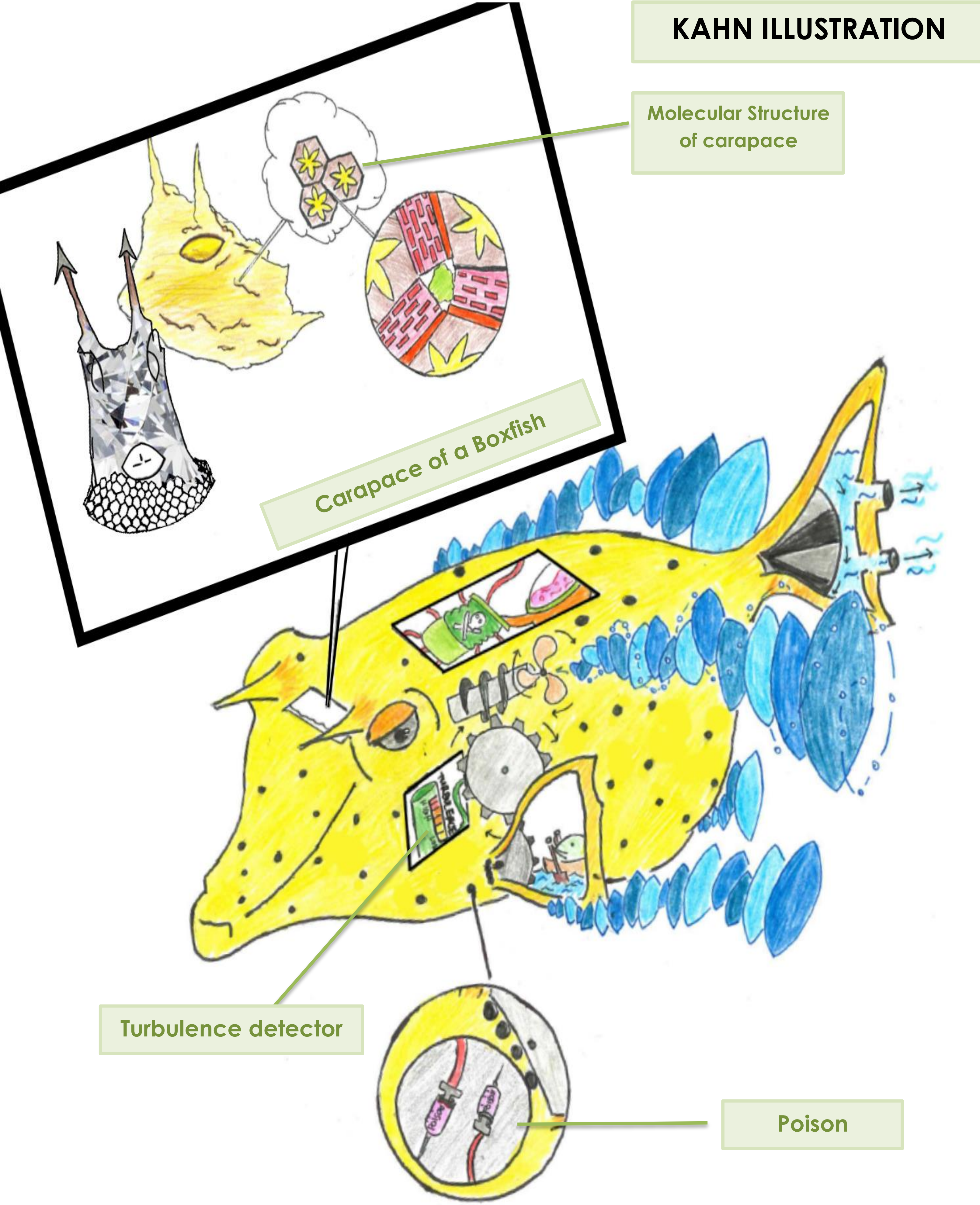
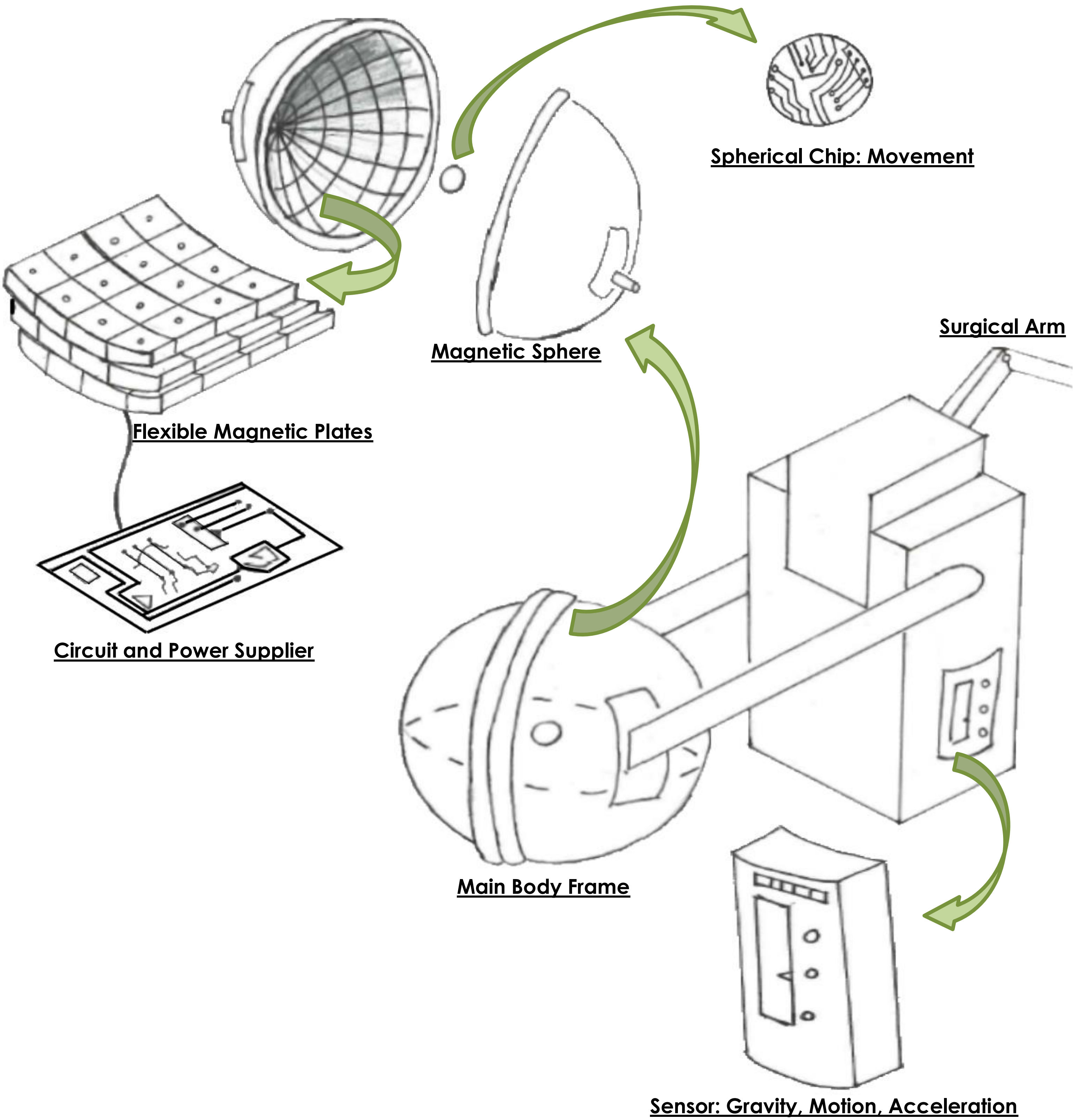

Boxfish
Challenge
Defer potential predators or threat
Defer current predators or threat
Strategy
Excretion of poisonous proteins from its skin
Strategy
Spike like formations at the tip of its carapace may deter predators
Strategy
A protective carapace made up of a collagen base and mineralized surface plates that resists tension
Challenge
Navigate the water
Design: Pest Control
Design: Aquatic Navigation
Strategy
Steering with its pectoral and tail fins
• Submarines
• Underwater Rovers
• Ships
Challenge
Remaining stable in turbulent water
Design
Material for Structural Integrity
Shell for Fragile Objects
• Foundations for buildings
• Walls
• Body of vehicles
• Casing
• Compartment for intricate experimental apparatus
Strategy
Creating a difference in pressure through the formation of water vortices
Mechanism for Structural Stability
Design
Mechanism to Prevent Shaking
• Prevent collapse of buildings due to resonance or calamities
• Surgical Improvements
• Aid for Parkinson's Disease

KAHN ILLUSTRATION



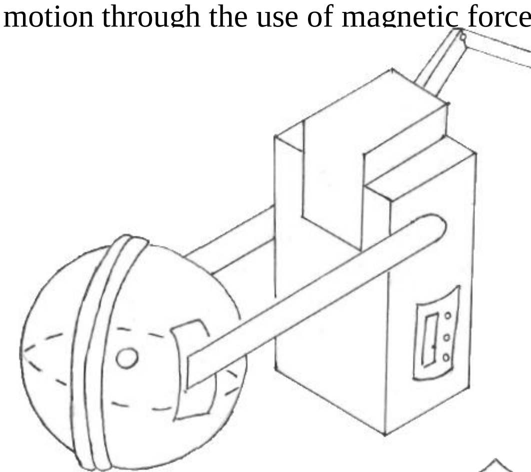
Bio-Inspired Design: Spherical Stabilizer



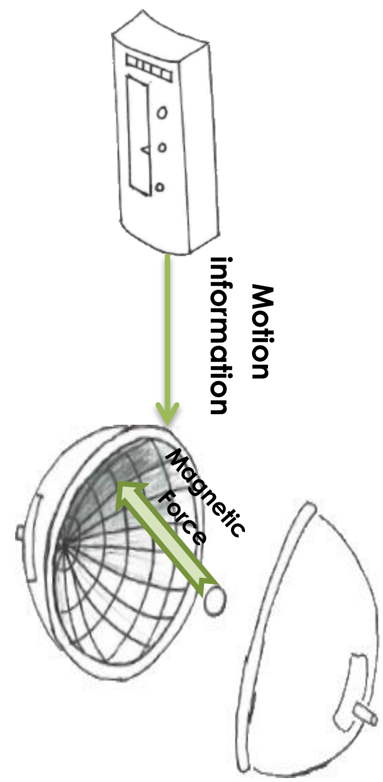
Bio-Inspired Solution Rationale

The mechanism of the design is inspired by the stabilizing capabilities of the boxfish. Akin to how the boxfish maintains stability through vortices of water, the Spherical Stabilizer allows deep-space surgical arms to remain stable in motion through the use of magnetic forces.

The main body frame of the solution is composed of an internally magnetized sphere, a spherical chip, a motion sensor, and a frame for the surgical arm to be fixed onto. The spherical chip is located inside the magnetized sphere, whilst motion sensors are placed at the sides of the machine. The motion sensor can also be placed elsewhere within the spacecraft.



The mechanism works by compensating for any sudden changes in movement. The motion sensor will sense some form of movement (e.g. gravitation transitions, acceleration). The sensor will then calculate the type of movement and its magnitude, and send this information to the magnetized sphere. The sphere is hollow with flexible magnetic plates placed around its inner walls. The plates are connected to a circuit that determine how powerful the magnetic force should be based on then information sent by the sensors. The spherical chip within the sphere will then move accordingly based on which areas of the sphere is magnetized. For instance, if a sudden increase in gravity is detected, the sensor will send its magnitude to the circuits. Since gravity acts downwards, the upper part of the sphere will have an increase in magnetic force, pulling the chip upwards, whilst it is pulled downwards by gravity. The magnitude of the magnetic force will match the force of gravity, keeping the chip stable at the orb's center (similar to the Milikan oil experiments). The chip then sends this compensation to the surgical arm, preventing it from being influenced by sudden changes in movement. If the arm is being pulled down by gravity, the magnetic plates will magnetize the chip upwards, thereby telling the arm to move upwards.



This machine can also be useful on Earth. It can be used by ambulances if an operation is needed right away. The stability created by the machine can compensate for the motion created by the ambulance's quick turns. It can also be used on intricate experiments that require highly stable hands. Hands often shake when dealing with intricate/fragile procedures (e.g. putting thread in a needle hole, lab experiments), and this mechanism can be used with smaller surgical arms to aid the accuracy and stability of these procedures.

Appendix: Photo Citation

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