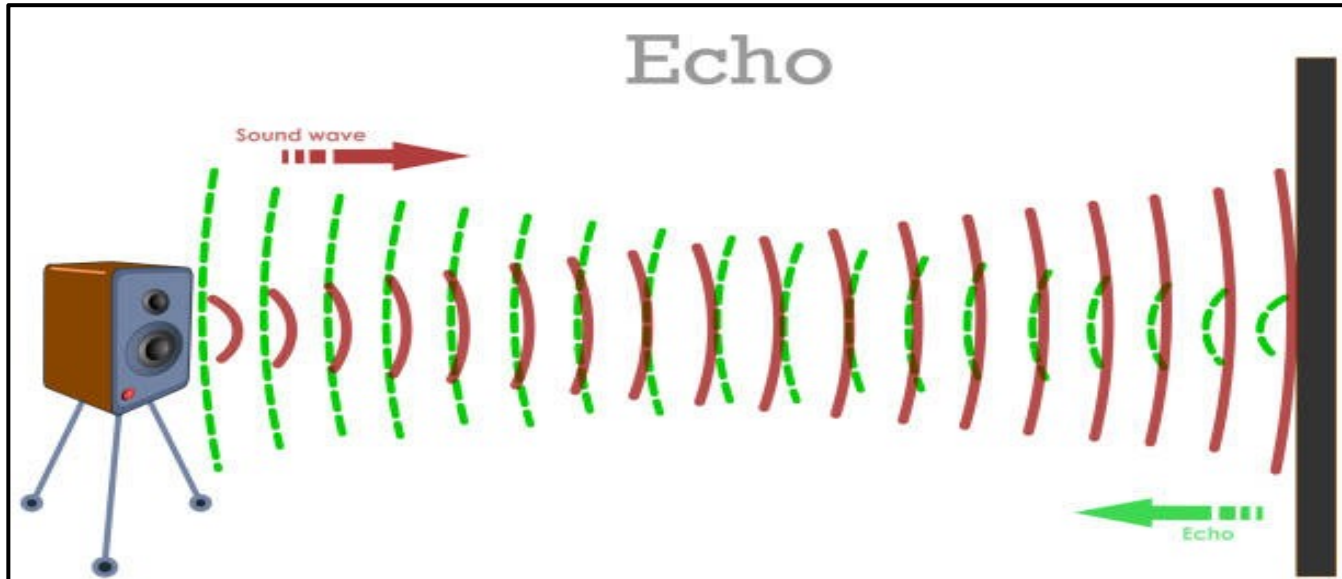


Biology for Engineers

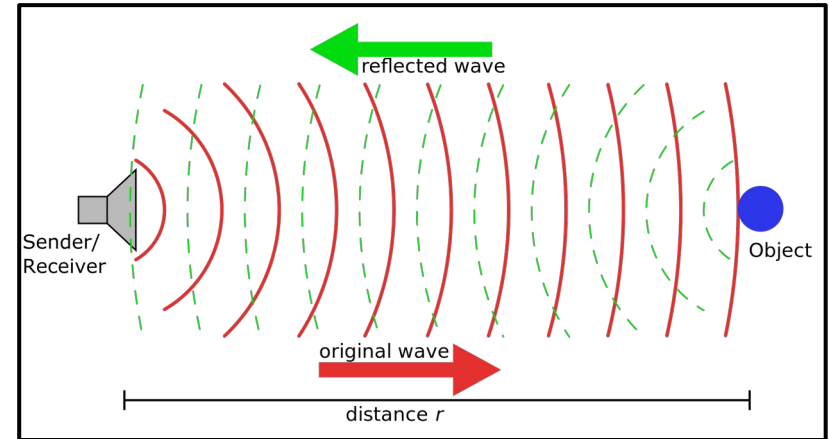
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Echolocation



What is Echolocation?

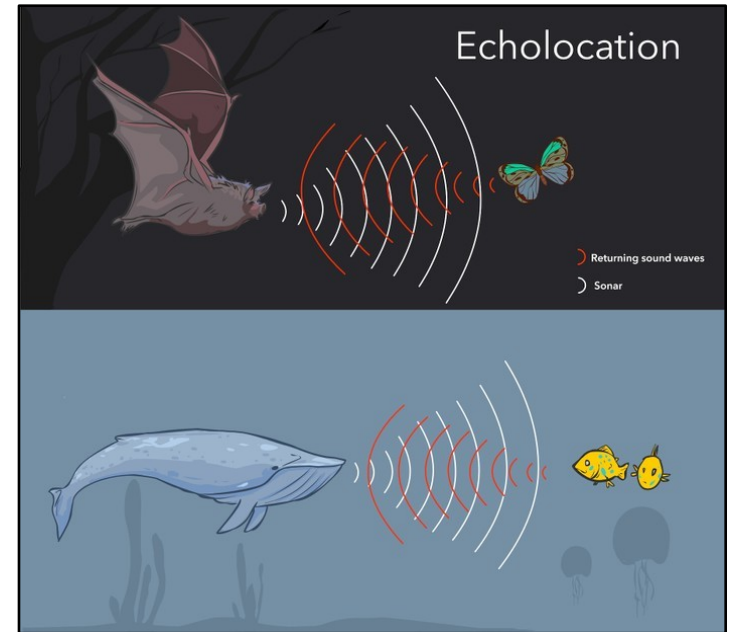
- **Echolocation** is a physiological process for locating distant or invisible objects (such as prey) by means of sound waves reflected back to the emitter by the objects.
- Echolocation is used for orientation, obstacle avoidance, food procurement, and social interactions.



Echolocation



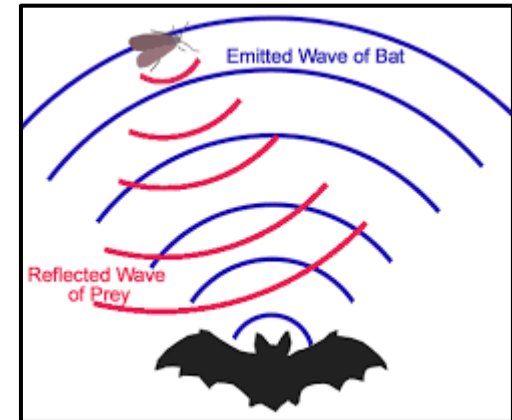
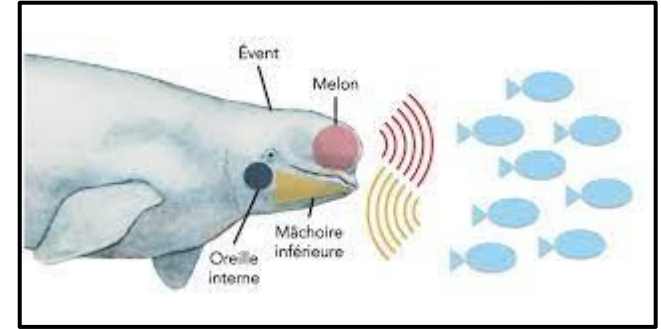
- Nature's own sonar system, **echolocation** occurs when an animal emits a sound wave that bounces off an object, returning an echo that provides information about the object's distance and size.
- Over a thousand animal species can sense echolocate, including most bats, whales, and small mammals.
- Many are nocturnal(active at night) burrowing, and ocean-dwelling animals that rely on echolocation to find food in an environment
- Animals uses several methods for echolocation, from vibrating their throats to flapping their



Echolocation



- For dolphins and toothed whales, this technique enables them to see in muddy waters or dark ocean depths, and may even have evolved so that they can chase squid and other deep-diving species.
- Echolocation allows bats to fly at night as well as in dark caves. This is a skill they probably developed so they could locate night-flying insects that birds can't find.





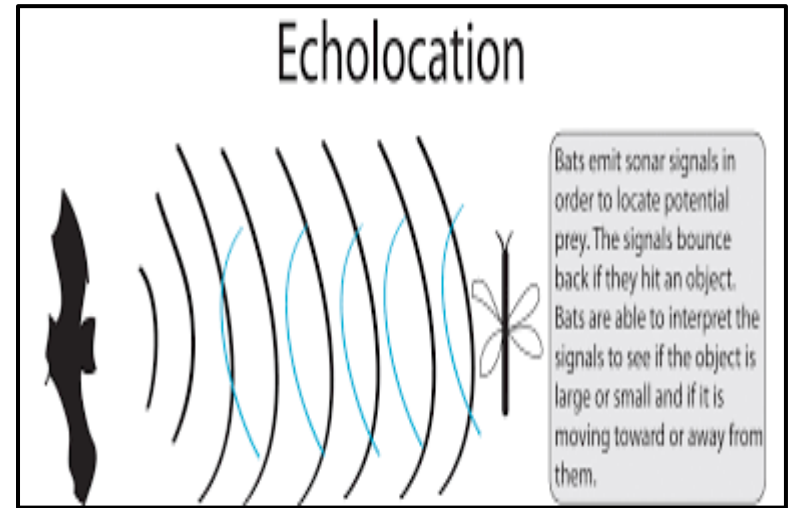
How do dolphins use echolocation?

- Dolphins and whales use echolocation by bouncing high-pitched clicking sounds off underwater objects.
- The sounds are made by squeezing air through **nasal passages near the blowhole**.
- These sound waves then pass into the **forehead**, where a fatty structure called the **melon** focuses them into a beam.
- If the echolocating waves hits the object, the reflected sound is picked up through the **animal's lower jaw** and passed to its **ears**.

- Echolocating sounds are so loud that the ears of dolphins and whales are **shielded** to protect them.
- Dolphins and whales use this method to work out an **object's distance, direction, speed, density and size**.
- Using echolocation, dolphins can detect an object the size of a golf ball, about the length of a football pitch away – much further than they can see.
- By moving its head to aim the sound beam at different parts of a fish, a dolphin can also differentiate between species.

How do bats use echolocation?

- Bats make echolocating sounds in their **larynxes** and emit them through their **mouths**. Fortunately, most are too high-pitched for humans to hear – some bats can scream at up to 140 decibels, as loud as a jet engine 30m away.
- Bats can detect an insect up to 5m away, work out its size and hardness, and can also avoid wires as fine as human hairs.
- As a bat closes in for the kill, it cranks up its calls to pinpoint the prey.
- To avoid being deafened by its own calls (sound), a bat **turns off its middle ear** just before calling, **restoring its hearing a second**



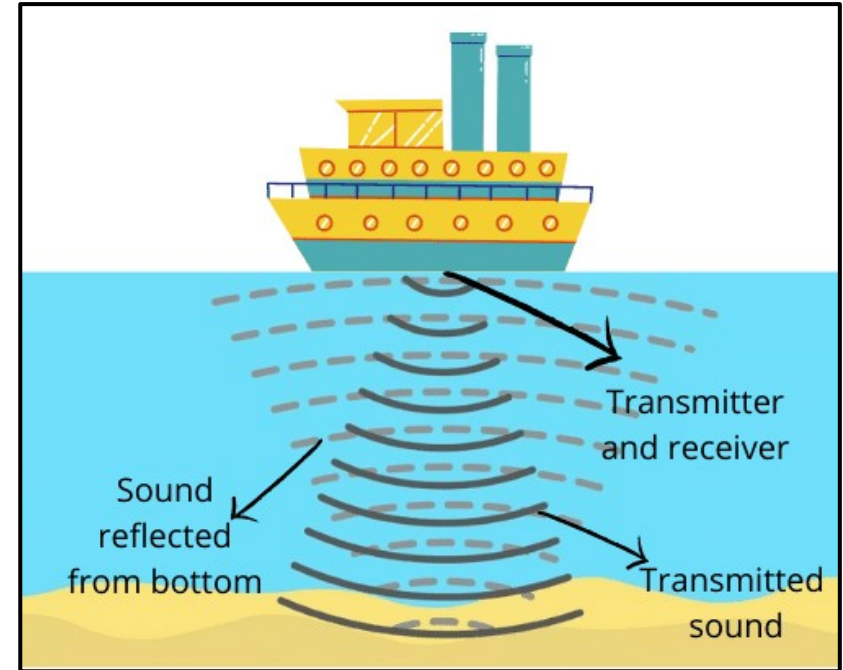
Sonar

- The full form of **Sonar** is **Sound, Navigation and Ranging**.
- **Sonar** is a technique for detecting and determining the distance and direction of underwater objects by acoustic means.
- Sound waves emitted by or reflected from the object are detected by sonar apparatus and analyzed for the information they contain.



Sonar

- Sonar systems may be divided into three categories.
- In **active sonar systems** an acoustic projector generates a sound wave that spreads outward and is reflected back by a target object. A receiver picks up and analyzes the reflected signal and may determine the range, bearing, and relative motion of the target.
- **Passive systems** consist simply of receiving sensors that pick up the noise produced by the target (such as a ship, submarine, or torpedo). Waveforms thus detected may be analyzed for identifying characteristics as well as direction and distance.
- The third category of sonar devices is **acoustic communication systems**, which require a projector and receiver at both ends of the acoustic path.





Sonar

- Sonar was first proposed as a means of **detecting icebergs**.
- Interest in sonar was heightened by the threat posed by submarine warfare in World War I.
- An early passive system, consisting of towed lines of microphones, was used to detect submarines
- Subsequent developments included the **echo sounder** or **depth detector**, **rapid-scanning sonar**, and **side-scan sonar**
- Sonar is also used in **acoustic homing torpedoes**, in **acoustic mines**, and **in mine detection**.
- Nonmilitary uses of sonar include **fish finding**, **depth sounding**, **mapping of the sea bottom**, **Doppler navigation**, and **acoustic locating for divers**.

Echolocation



ULTRASONOGRAPHY

- A procedure that uses high-energy sound waves to observe tissues and organs of the body.
- Ultrasound frequencies range from 2 to approximately 15 MHz,
- The **sound waves** make **echoes** that form pictures of the **tissues and organs** on a **computer** screen (sonogram).
- Ultrasonography may be used to help **diagnose diseases**, such as **cancer**.
- It may also be used during **pregnancy** to check the fetus (unborn baby) and during medical procedures, such as biopsies.
- Also called **ultrasound**.



Ultrasonography

- Diagnostic ultrasound, also called sonography or diagnostic medical sonography, is an imaging method that uses sound waves to produce images of structures within your body.
- The images can provide valuable information for diagnosing and directing treatment for a variety of diseases and conditions.
- Most ultrasound examinations are done using an ultrasound device **outside your body**, though some involve placing a small device **inside your body**.





Why Ultrasound is done?

Ultrasound is used for many reasons, including to:

- ✓ View the uterus and ovaries during pregnancy and monitor the developing baby's health
- ✓ Diagnose gallbladder disease
- ✓ Evaluate blood flow
- ✓ Guide a needle for biopsy or tumor treatment
- ✓
- ✓ Check the thyroid gland
- ✓ Find prostate problems
- ✓ Assess joint inflammation
- ✓ Evaluate metabolic bone disease



Risks and Limitations

- Diagnostic ultrasound is a safe procedure that uses low-power sound waves.
- There are **no known risks**.
- Ultrasound is a valuable tool, but it has limitations.
- Sound waves don't travel well through air or bone, so ultrasound isn't effective at imaging body parts that have gas in them or are hidden by bone, such as the lungs or head.
- Ultrasound may also be unable to see objects that are located very deep in the human body. To view these areas, other imaging tests such as CT or MRI scans or X-rays can be performed.



Procedure

Ultrasound imaging, or ultrasonography (US), uses high-frequency sound pulses that are emitted from a hand-held ultrasound transducer, or probe.

- The transducer is applied to the patient's skin via a **coupling gel**, and the sound pulses are reflected back to the **transducer** from structures within the patient.
- The magnitude of the reflected sound, or “echo,” is converted into a **gray-scale image**.
- **Tissues that are highly reflective of the sound, or “echogenic,” such as bone, appear bright.**
- **Tissues that allow transmission of the sound pulses, or are poorly echogenic, such as fluid, appear dark or black.**



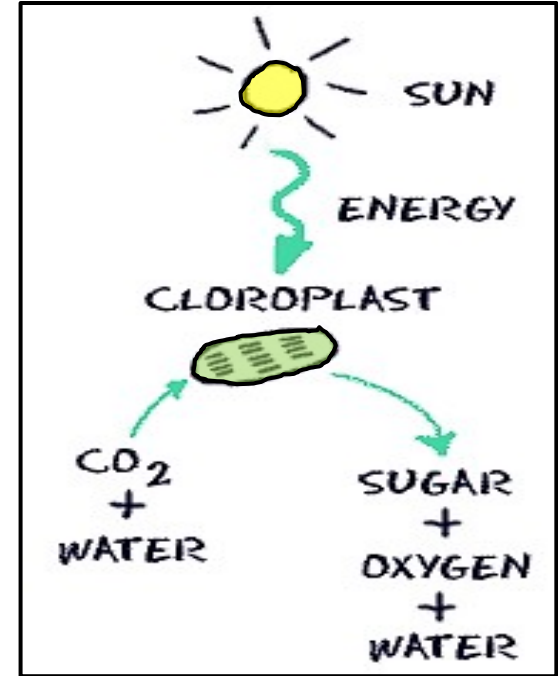
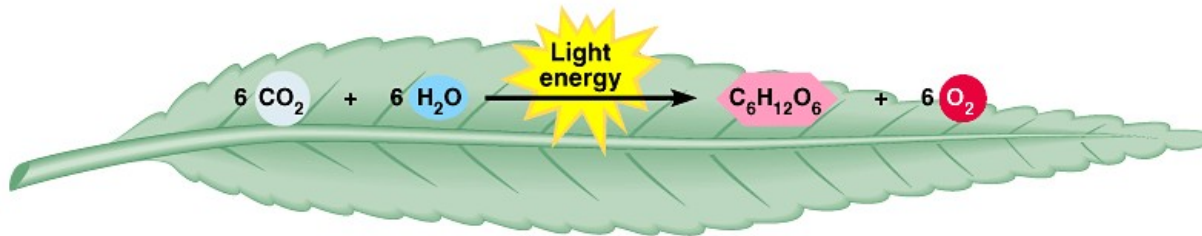
- Sometimes, ultrasounds are done inside your body.
- In this case, the transducer is attached to a probe that's inserted into a natural opening in your body.
- Examples include:

Transesophageal echocardiogram: A transducer, inserted into the esophagus, obtains heart images. It's usually done while under sedation.

Transrectal ultrasound: This test creates images of the prostate by placing a special transducer into the rectum.

What is Photosynthesis?

- **Photosynthesis** is a process used by plants and other organisms to convert light energy into chemical energy.
- In simple terms, **Photosynthesis** is the process by which plants use sunlight, water, and carbon dioxide to create oxygen and energy in the form of sugar.

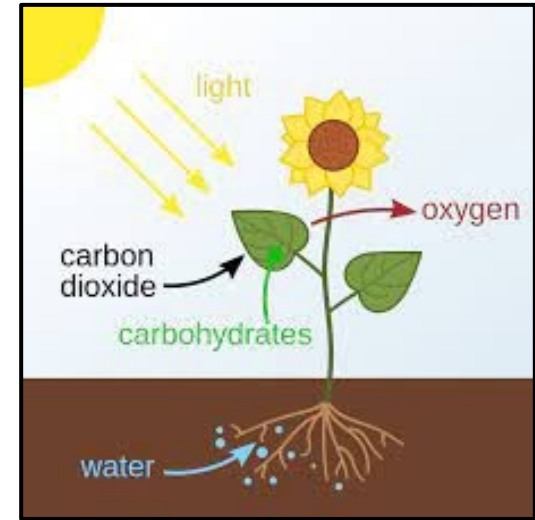


Photosynthesis



Photosynthesis has 3 major events:

1. Sunlight is converted into chemical energy
2. Water (H_2O) is split into oxygen (O_2)
3. Carbon dioxide (CO_2) is fixed into sugars ($\text{C}_6\text{H}_{12}\text{O}_6$)



Photosynthesis is carried out by: These organisms are known as **photoautotrophs** or **producers** meaning they make their own food and energy from the sun.

Plants



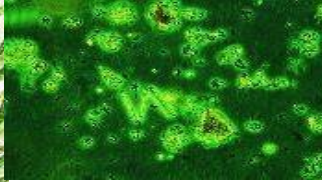
Some bacteria



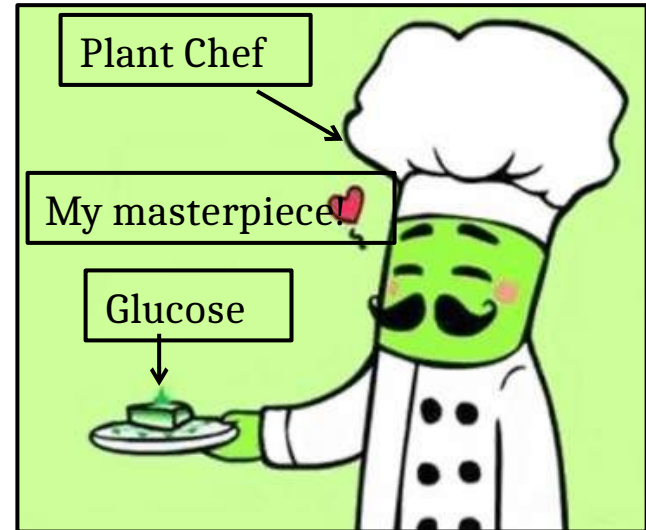
Algae



Cyanobacteria



Phytoplankton



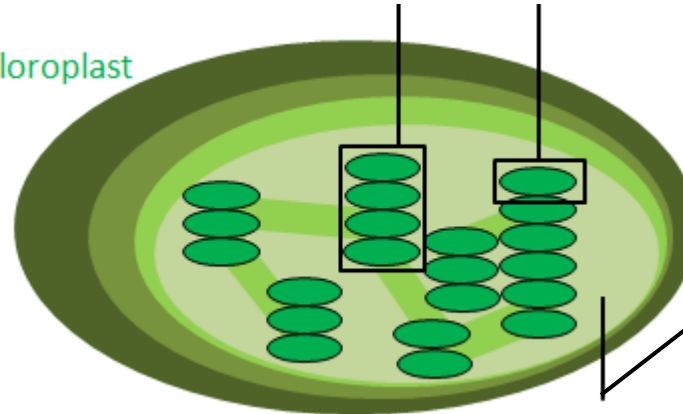
Where Photosynthesis occurs?

Through evolution, plant cells, certain bacteria and some algae have acquired **chloroplasts** to help carry out the photosynthetic reaction. Chloroplasts are also known as plastids, is a plant cell organelle.

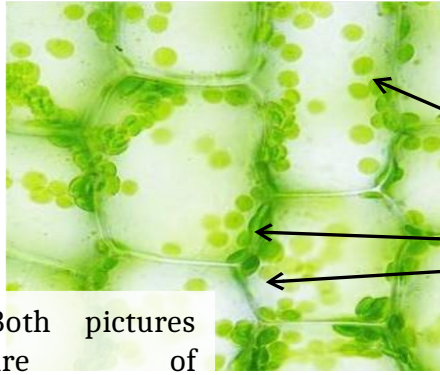
Chloroplasts are full of round flattened discs called **thylakoids**.

A stack of thylakoids is called a **granum**

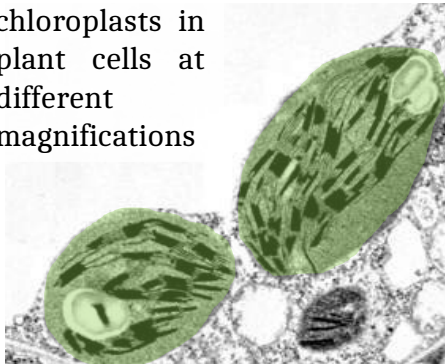
Chloroplast



Stroma is the space inside chloroplasts

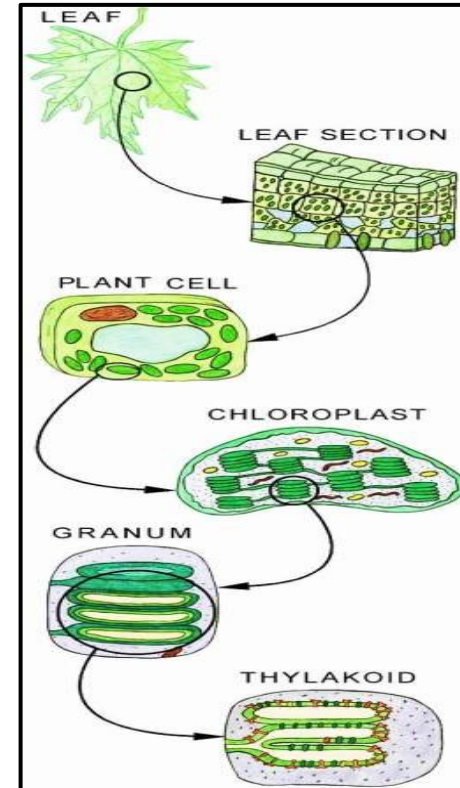


Both pictures are of chloroplasts in plant cells at different magnifications



Photosynthesis

- The thylakoid membranes are lined by pigments such as chlorophyll and carotenoids.
- **Chlorophyll** is a green pigment and is the most abundant.
- Chlorophyll absorbs all wavelength colors except green, which is reflected off giving plants their green appearance.
- These pigments harvest light energy packets or **photons** when they absorb sunlight.





The Photosynthesis Reaction is divided into two parts:

Light Reaction

- Light reactions or light dependent reactions.
- It capture light energy to power photosynthesis.
- Light reactions occur during the day time.
- They take place in the **thylakoids**.
- Pigments in the thylakoid membranes form protein complexes called **Photosystem I** and **Photosystem II**.
- These photosystems harvest photons to charge up energy carrying molecules that will power the dark reactions.

Dark Reaction

- Dark reactions or light independent reactions.
- It do not need light energy to power their reactions and can occur day or night.
- Dark reactions occur in the **stroma** of chloroplasts (the space that surrounds thylakoids) and fix carbon dioxide into glucose.

Photovoltaic cells

A **solar cell**, or **photovoltaic cell**, is an electronic device that converts the energy of light directly into electricity.

1. How do solar cells work?

A solar panel works by allowing particles of light, or photons, to knock electrons free from atoms, generating a flow of electricity.

2. What is the principle of solar cells?

Silicon crystals are laminated into p-type and n-type layers, stacked on top of each other. Light striking the crystals induces the “photovoltaic effect,” which generates electricity.

3. What does the solar cell include?

Solar cell consists of a crystalline silicon solar panel which is a series of interconnected silicon cells joined together to form a circuit.

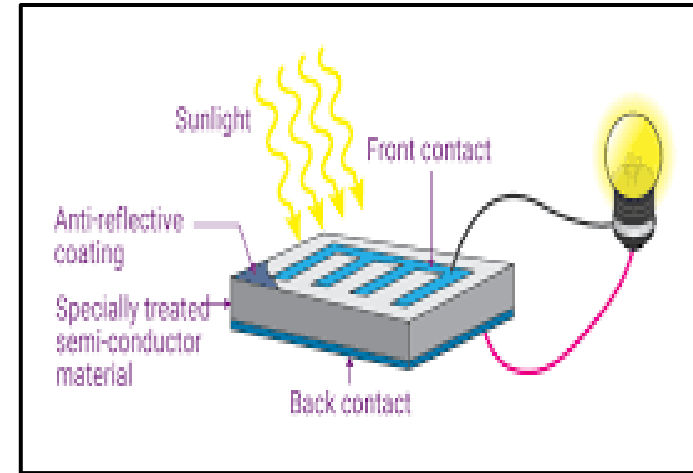
4. Can solar power from photovoltaic cells be harnessed in the absence of sunlight?

No, it can be only harnessed in the presence of sunlight.



Photovoltaic cells

- Photovoltaic cells consist of two or more layers of semiconductors (silicon) with one layer containing **positive charge** and the other **negative charge** lined adjacent to each other.
- Sunlight, consisting of small packets of energy termed as **photons**, strikes the cell, where it is either reflected, transmitted or absorbed.
- When the photons are absorbed by the negative layer of the photovoltaic cell, the energy of the photon gets transferred to an electron in an atom of the cell.
- With the increase in energy, the electron escapes the outer shell of the atom.
- The freed electron naturally migrates to the positive layer creating a potential difference between the positive and the negative layer. When the two layers are connected to an external circuit, the electron flows through the circuit, creating a current.





Advantages of Photovoltaic cells

Environmental Sustainability: Photovoltaic cells generate clean and green energy as no harmful gases such as CO_x , NO_x etc are emitted.

Economically Viable: The operation and maintenance costs of cells are very low.

Accessible: Solar panels are easy to set up and can be made accessible in remote locations or sparsely inhabited areas at a lesser cost as compared to conventional transmission lines.

Renewable: Solar energy is renewable and abundant in nature

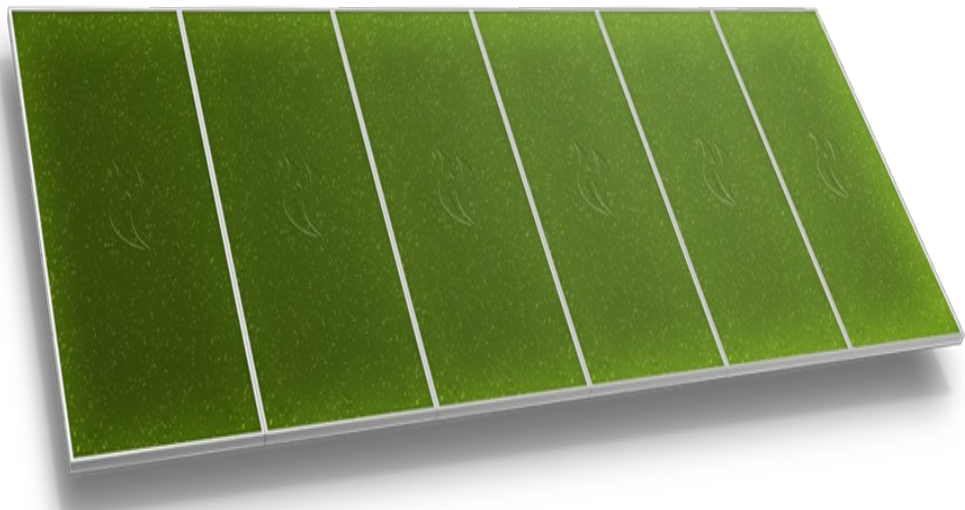
Cost: Solar panels have no mechanically moving parts except in some highly advanced sunlight tracking mechanical bases.

Cost effective maintenance

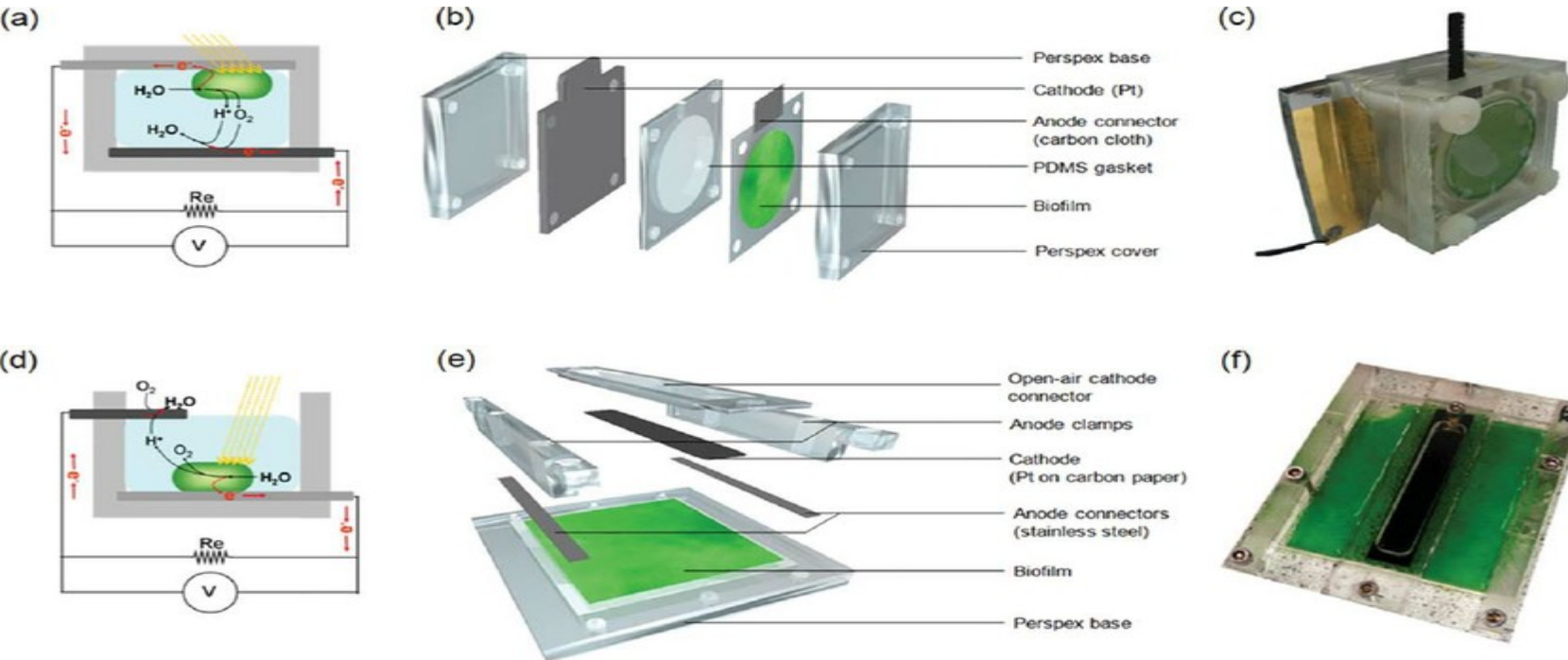
Algal based Bio-solar panels

- Algae can be potential used to boost silicon solar module efficiency by 4% and thin film by 36%.
- The algae materials are added to the encapsulant in silicon-based modules or to the anti-reflective coating on the glass of thin film modules.
- The team cultivates single-celled photosynthesizing algae called diatoms to extract their shells, which reportedly have unique light-manipulating properties, including blocking ultraviolet (UV) light.
- The diatom shells are added to the encapsulant of silicon modules or to the anti-reflective coating on the glass of thin film modules, which could boost their efficiency by 4% and 36%, respectively

Algal based solar panels



Bio-photovoltaic cells





Disadvantages of Photovoltaic cells

- The efficiency of solar panels is low compared to other renewable sources of energy.
- Energy from the sun is intermittent and unpredictable and can only be harnessed in the presence of sunlight. Also, the power generated gets reduced during cloudy weather.
- Long-range transmission of solar energy is inefficient and difficult to carry. The current produced is DC in nature and the conversion of DC current to AC current involves the use of additional equipment such as inverters.
- Photovoltaic panels are fragile and can be damaged relatively easily. Additional insurance costs are required to ensure a safeguard of the investments.

Applications of Photovoltaic cells

Vehicular applications

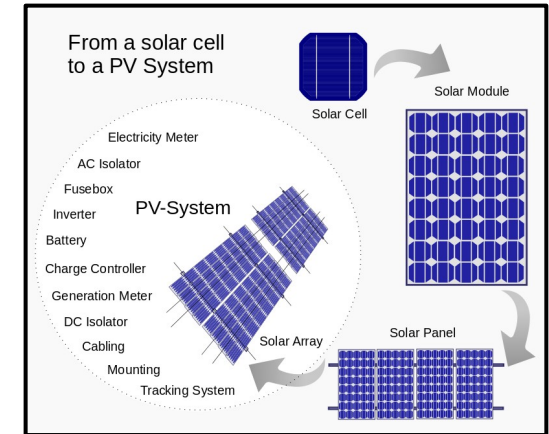
- Application of solar cells as an alternative energy source for vehicular applications is a growing industry.
- Electric vehicles that operate off of solar energy and/or sunlight are commonly referred to as solar cars.
- These vehicles use solar panels to convert absorbed light into electrical energy that is then stored in batteries.
- Batteries in solar-powered vehicles differ from those in standard ICE cars because they are fashioned in a way to impart more power towards the electrical components of the vehicle for a longer duration.
- The first instance of photovoltaic cells within vehicular applications was around midway through the second half of the 1900's.
- **Sunrayer** vehicle by **General Motors** that achieved speeds of over 40 mph.



Applications of Photovoltaic cells

Cells, modules, panels and systems

- Multiple solar cells in an integrated group, all oriented in one plane, constitute a solar photovoltaic panel or module. Photovoltaic modules often have a sheet of glass on the sun-facing side, allowing light to pass while protecting the semiconductor wafers. Solar cells are usually connected in series creating additive voltage. Connecting cells in parallel yields a higher current.
- Although modules can be interconnected to create an array with the desired peak DC voltage and loading current capacity, which can be done with or without using independent MPPTs (maximum power point trackers) or, specific to each module, with or without module level power electronic (MLPE) units such as microinverters or DC-DC optimizers. Shunt diodes can reduce shadowing power loss in arrays with series/parallel connected cells.



Bionic Leaf

- The **Bionic Leaf** is a biomimetic system that gathers solar energy via photovoltaic cells that can be stored or used in a number of different functions.
- Bionic leaves can be composed of both synthetic (metals, ceramics, polymers, etc.) and organic materials (bacteria), or solely made of synthetic materials.
- The Bionic Leaf has the potential to be implemented in communities, such as urbanized areas to provide clean air as well as providing needed clean energy.
- In 2009, first developed the "artificial leaf", a device made from silicon and an anode electrocatalyst for the oxidation of water, capable of splitting water into hydrogen and oxygen gases.

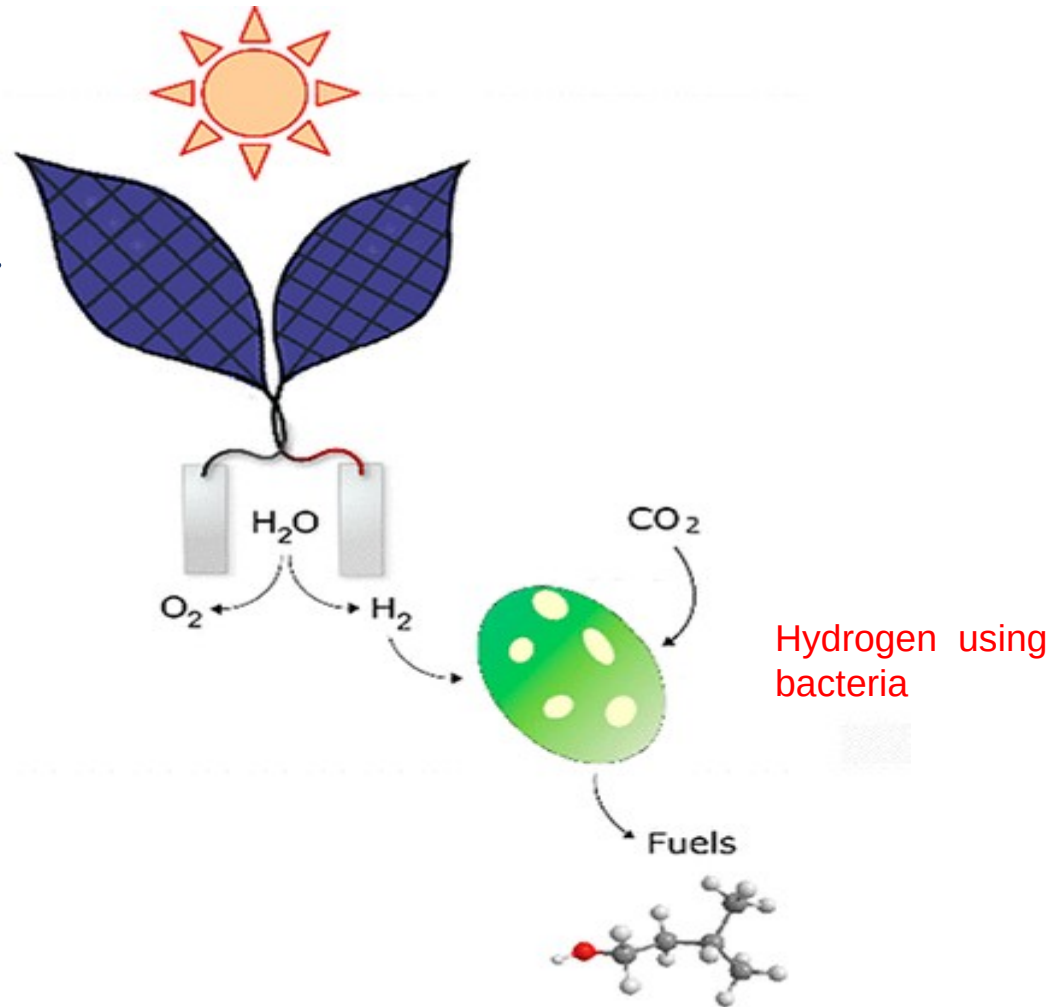


- In natural photosynthesis, [photosynthetic organisms](#) produce energy-rich organic molecules from water and carbon dioxide by using solar radiation.
- The process of photosynthesis [removes carbon dioxide](#) a [greenhouse gas](#) from the air.
- Artificial photosynthesis, as performed by the Bionic Leaf, is approximately 10 times more efficient than natural photosynthesis.
- Using a catalyst, the Bionic Leaf can remove excess carbon dioxide in the air and convert that to useful alcohol fuels, like [isopropanol](#)

- The bionic leaf is an artificial leaf, which efficiently splits water into hydrogen and oxygen gas by pairing silicon — the material that makes up solar panels
- The hydrogen gas can be stored on site .
- Biology at Harvard Medical School, to explore their device uses a photovoltaic panel to split the water into oxygen and hydrogen and then feeds the hydrogen to the microbes, which convert CO₂ from the air into fuels such as alcohol.
- The first version of the device, which debuted in 2015, was able to produce just over 200 milligrams of fuel per liter of water new uses for the technology.

Bionic leaf

Artificial leaf →
{Bionic leaf}
Bionic leaf can be
considered as
Photovoltaic cells to
split water



Biology for Engineers

Nature-Bioinspired Materials and Mechanisms (Module-4)

Plant burrs (Velcro) - Overview

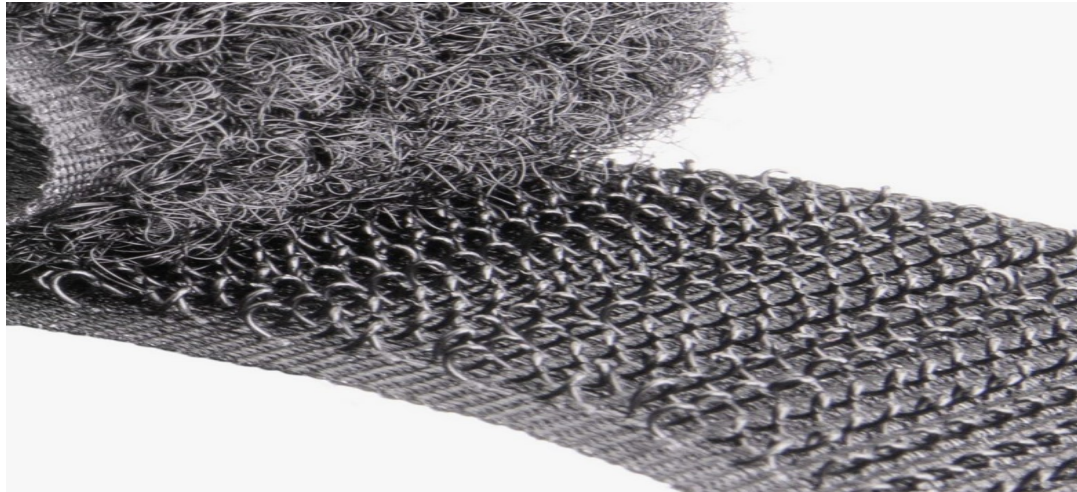


- Scientists and engineers use what nature shows us to develop some of the most innovative technologies, such as a seahorse tail for a mechanical arm or kingfisher's bill for a bullet train design.
- One of the older biomimicry examples is Velcro
- Velcro was inspired by burr seeds, which are covered in tiny hooks that easily attach to mammal fur.
- Velcro has one side made up of tiny hooks, while the other side is covered in tiny loops.

Velcro consisting of two strips of nylon fabric, one having tiny hooked threads and the other a coarse surface, that form a strong bond when pressed together.

The fastener consisted of two components: a lineal fabric strip with tiny hooks that could 'attach with another fabric strip with smaller loops, attaching temporarily, until pulled apart.

Initially made of cotton, which proved impractical, the fastener was eventually constructed with nylon and polyester.

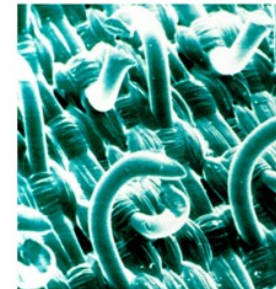


Biology for Engineers

Nature-Bioinspired Materials and Mechanisms (Module-4)

Plant burrs (Velcro) - Overview

- Small hooks enable seed-bearing burr to cling to tiny loops in fabric.
- Velcro fastening was invented in 1941 by Swiss engineer George de Mestral, who took the idea from the burrs that stuck to his dog's hair.
- Under the microscope he noted the tiny hooks on the end of the burr's spines that caught anything with a loop - such as clothing, hair or animal fur.
- The 2-part Velcro fastener system uses strips or patches of a hooked material opposite strips or patches of a loose - looped weave of nylon that holds the hooks

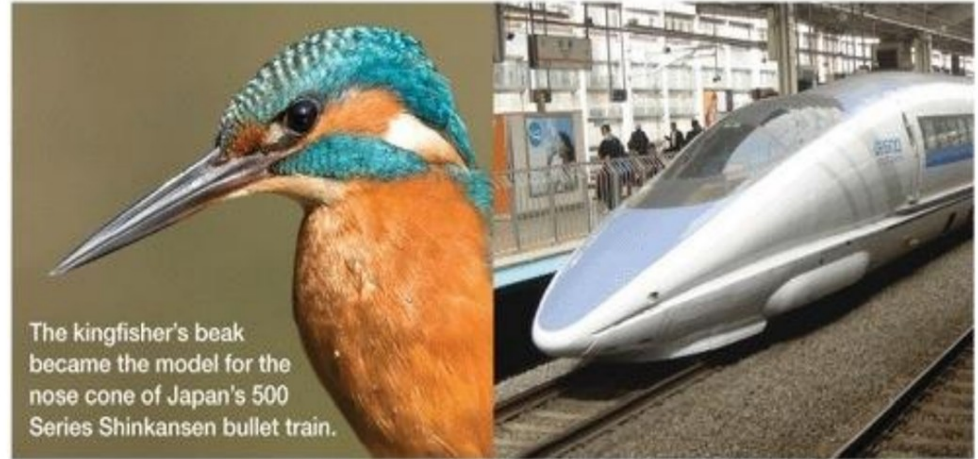


Biology for Engineers

Nature-Bioinspired Materials and Mechanisms (Module-4)

Bullet train design – Kingfisher beak

- The fastest train in the world at speeds of up to 200 miles per hour, Japan's Shinkansen Bullet Train was a marvel of modern technology.
- But there was one major problem after its initial debut: noise. Each time the train emerged from the tunnel, it caused a change in air pressure that caused thunder-like sounds that were a nuisance from a quarter of a mile away.
- The train's chief engineer, a bird-watcher, had an idea: taking inspiration from the shape of a bird's beak to make it more aerodynamic.
- The resulting design was based on the narrow profile of a kingfisher's beak, resulting in a quieter train that also consumes 15% less electricity and goes 10% faster than before.



The kingfisher's beak became the model for the nose cone of Japan's 500 Series Shinkansen bullet train.

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Biology for Engineers

Nature-Bioinspired Materials and Mechanisms (Module-4)



Bullet train design – Kingfisher beak

- In 1990s, bullet trains created loud boom sound when moving through tunnels.
- This was due to air cushion building in front of the train moving at high speeds.
- An engineer had witnessed a kingfisher bird diving down through the air, going into the water and creating very little splash

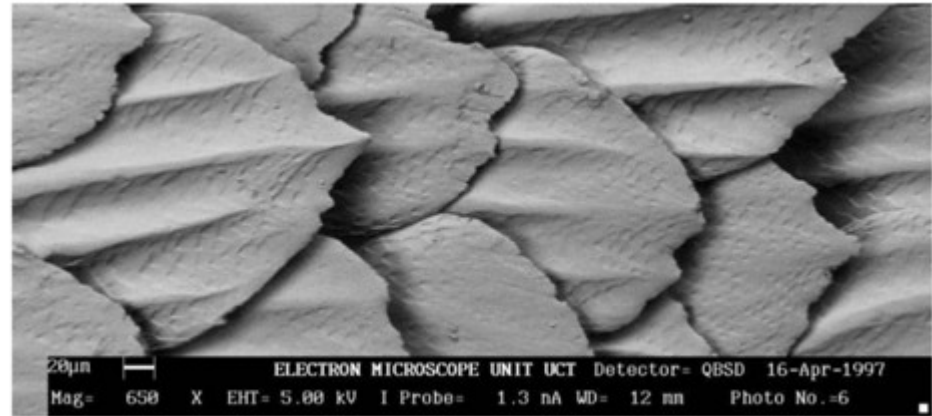
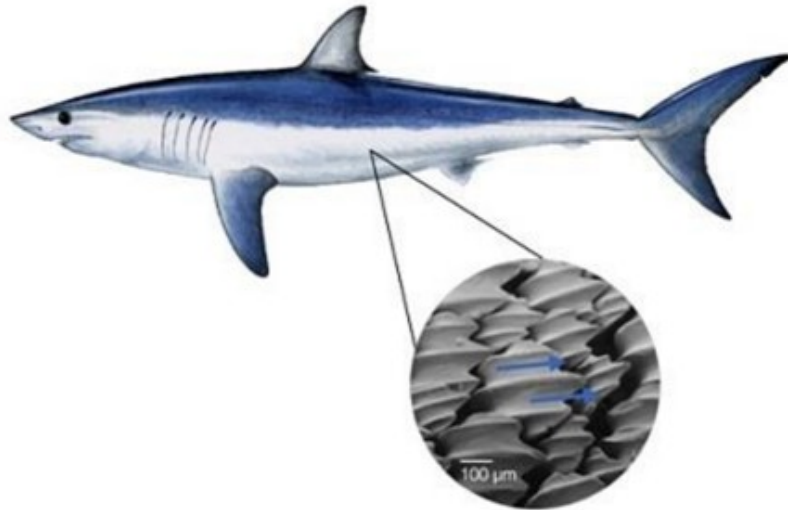


Biology for Engineers

Nature-Bioinspired Materials and Mechanisms (Module-4) Sharkskin (Friction reducing swimsuits)



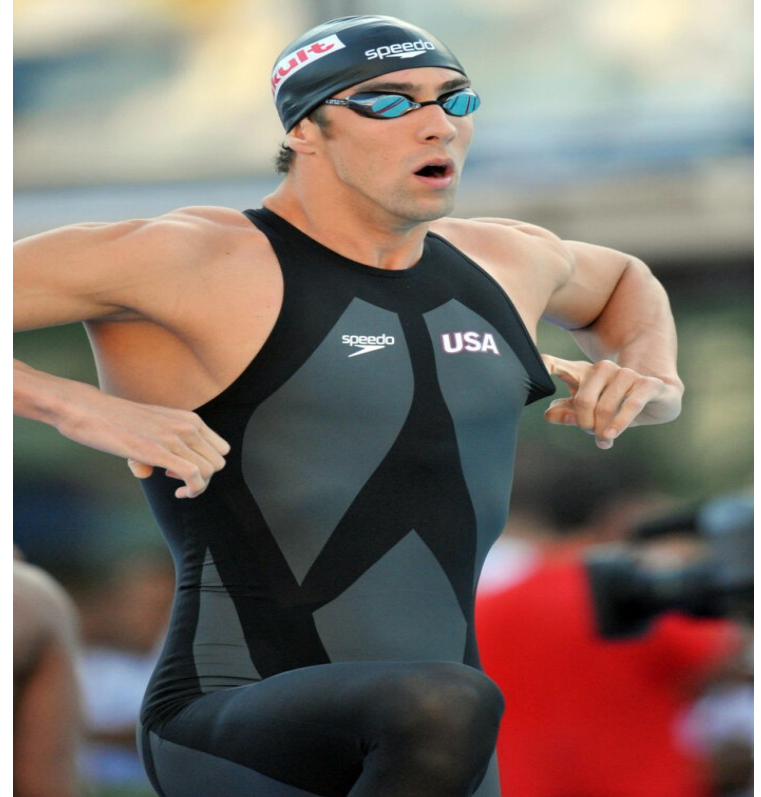
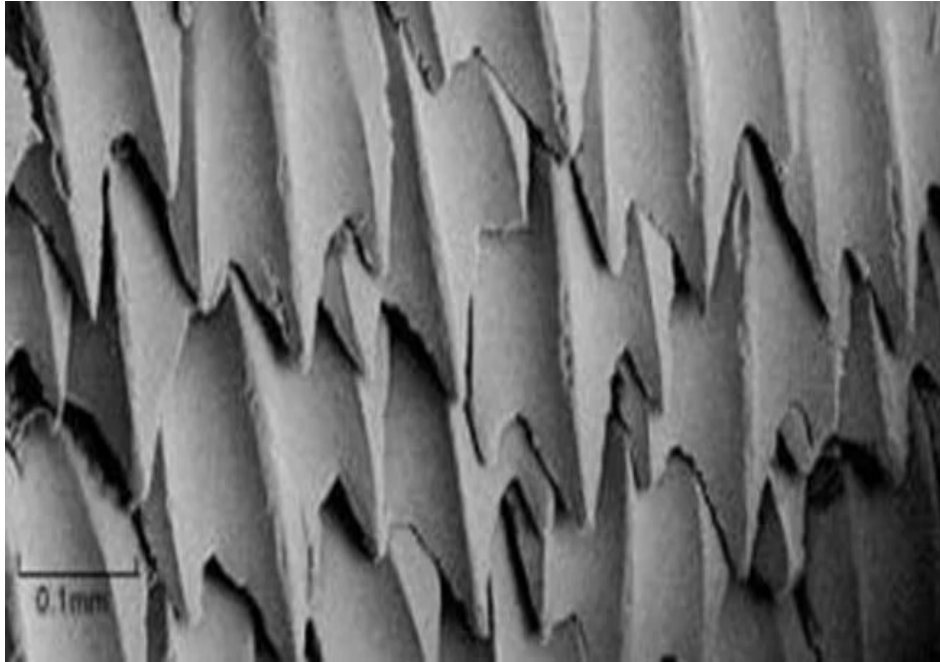
- Shark skin is constructed of overlapping scales.
- Nature through evolution, has ensured that water flows over the scales extremely efficiently, helping the shark to reach high speeds.



Biology for Engineers

Nature-Bioinspired Materials and Mechanisms (Module-4)

Sharkskin (Friction reducing swimsuits)



Bird flying (GPS and aircraft),

GPS

The **Global Positioning System (GPS)**, is a **satellite-based radio navigation** that provides **geolocation** and **time information** to a **GPS receiver** anywhere on or near the Earth

GPS Components : Comprises of ***satellites(space segment)***, ***ground stations (control segments)*** and ***receivers***. (user segments)

Satellites send signals. The *ground stations* uses the radar to track the satellites positions

The *receiver* is a device that might find in phone in car and continuously obtained signals from the satellites.

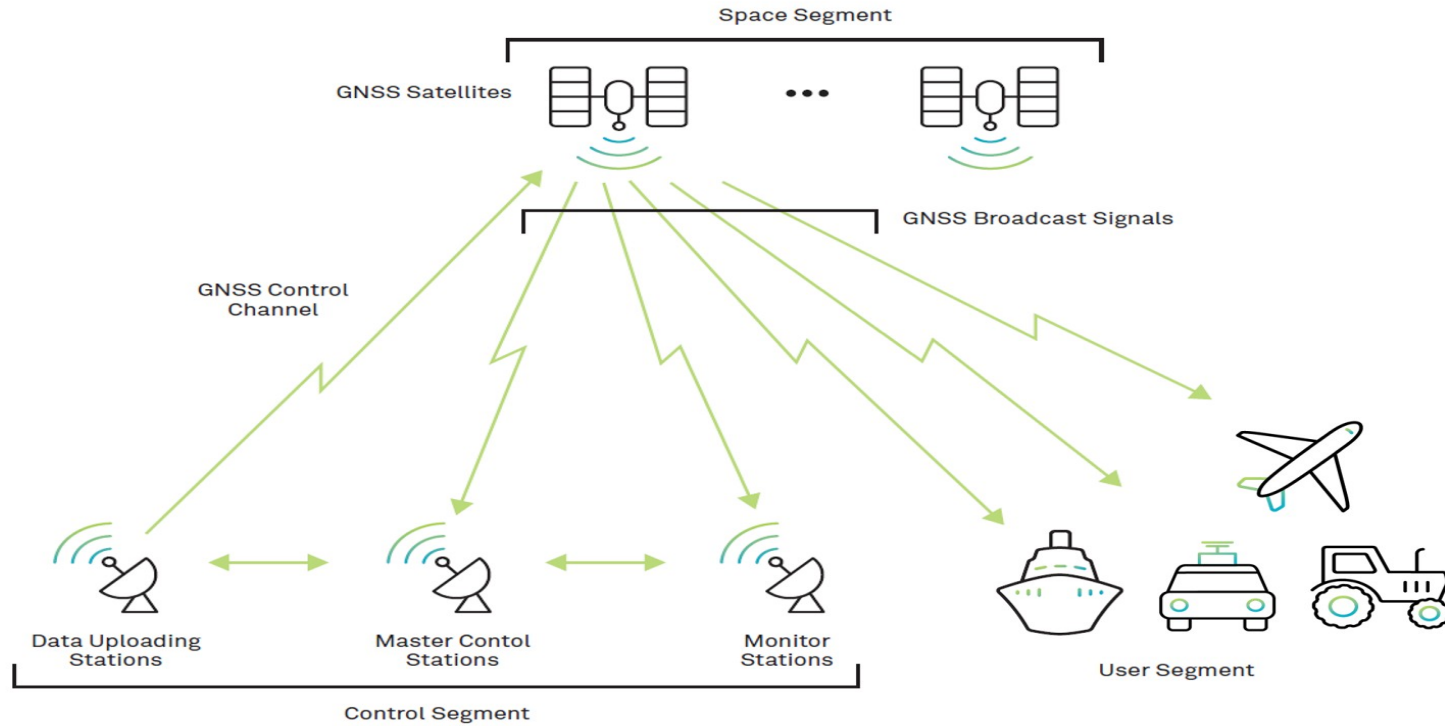
How does GPS work

- The GPS space segment includes over 30 satellites in orbit operated
- These satellites broadcast radio signals to control and monitoring stations on Earth
- Relay directly to users requiring highly precise satellite positioning.
- The receivers find out how far away they are from some other place
- Once receiver calculates its distance from four or more satellites, it knows exactly where you are
- They can usually determine where you are within a few yards of your actual location.
- More high-tech receivers can figure out where you are to within a few inches!

Global Positioning System applications generally fall into 5 major categories:

1. Location – determining a position
2. Navigation – getting from one location to another
3. Tracking – monitoring object or personal movement
4. Mapping – creating maps of the world
5. Timing – bringing precise timing to the world

How GPS works



GPS and Bird Flight

- Birds flight journey from one place to another place over a distance of few km to thousands. Birds brain works like GPS to find out the path of journey and distance
- Birds flight journey uses earth magnetic field.
- Bird can also visually detect magnetic fields, which provides them with a visual compass to guide their journey over long distances. Changes in the magnetic field are visible to birds.
- Scientists have identified a protein in the eyes of some bird and is responsible for analyzing magnetic field .

- Birds use magnetic field innovatively for navigating, just like a GPS, and also carry the capacity to turn it on and off.
- Researchers from US and Canada discovered a region of the brain which is called cluster N that is used by birds to detect and process the magnetic field of the Earth.
- Researchers identified 53 cells in the Pigeons brain that record detailed information on earths magnetic field , like a kind of internal GPS.

Experiment

Pigeons were held in a dark rom and used 3D coil system to cancel out earth natural magnetic field

- Replaced by tunable artificial magnetic field inside the room
- During adjustment of elevation angles and magnitude of artificial magnetic field, they simultaneously recorded the activity of 53 neurons (nerve cells) in the pigeons brain well in advance
- They measured electric signals from each neuron as the magnetic field was changed and found that every neuron had its characteristic response to the magnetic field almost like 3D compass reading north–south directions.
- Hence, birds magnetic navigation arises in cells that contain tiny metal in their nose or beaks.

- The birds like to use magnetically sensitive proteins called cryptochromes which are located in their retinas that enable their signalling and sensing functions, helping the birds in navigating the long distances they travel while migrating.
- It shows that birds already had natural GPS before the invention of our GPS
- In reality birds has several time edge over our GPS



Bird and Aircraft flying : Aerodynamics

Principles and Aerodynamics of flight in birds

- Fundamentally, bird and aircraft flying are similar
- Both bird and aircraft sustain on four aerodynamic of flight forces such as , lift, thrust, drag and weight
- Birds flap their wings to generate lift and thrust, when they stop flapping and keep their wings stretched out, the wings actively produce lift
- Lift is the component of aerodynamic forces perpendicular to the flow direction.

Flight in nature:

- Unlike airplanes birds have either flapping or oscillating wings (hummingbird).
- Birds have also the capabilities of adjusting the shape of the wing according to immediate flight situation

Aerodynamics of Birds wings:

- Wings provides the main dynamic control for the bird. Helps in gliding and swapping
- The lift and thrust is generated by wings, as opposed to aircraft that uses both wings and engines, control both speed and direction
- The lift force is produced by the action of airflow on the wings
- In order to generate thrust and lift during flight, birds change their wing shape
- During flight, wings will be bent inwards during upstroke, and extended & straightened during downstroke. It minimizes drag and maximizes thrust and consequently ,energy effi

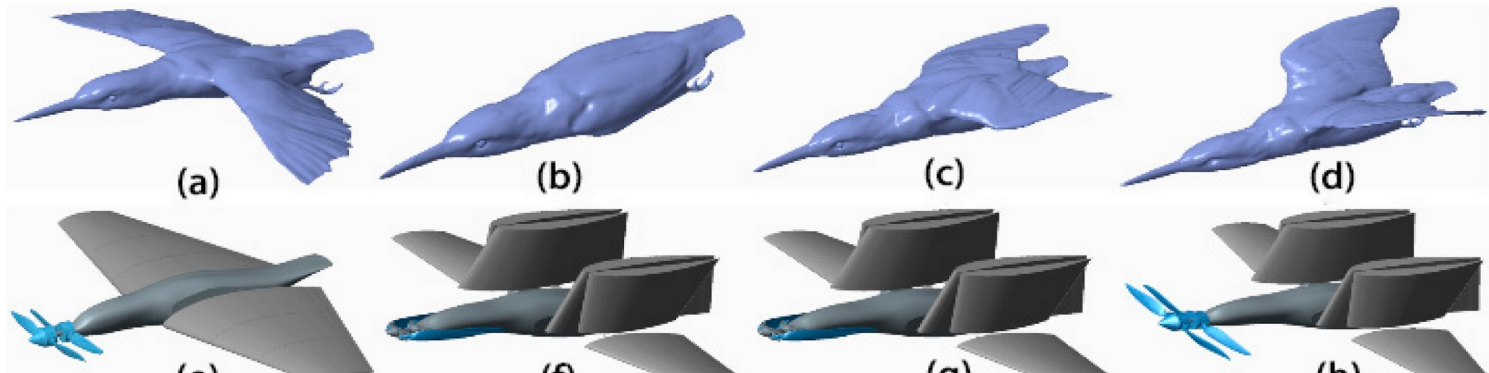


Gliding motion

- In gliding, the wings are held out to the side of the body and do not flap.
- Lift force is produced by the action of airflow on the wings. The lift force occurs because the air has a lower pressure just above the wings and higher pressure below.
- Gliding always results in a bird moving downward through the air.

Weight

The weight of both bird and aircraft are very light . The light weight of birds is due to the nature of low density bones, which are fundamentally light for mini



Comparison between Bird and aircraft flight

- Airplanes are man-made while birds are naturally born.
- Birds flap their wings to fly while airplanes have engines, electrical wires, cables and require fuel to fly.
- Airplanes need fuel to operate while birds require energy from food
- Birds have feathers while the airplane does not.
- Bird's wings provide lift and thrust while the airplane's wings have an airfoil shape that only provide lift.
- Bird's can change their wingspan's shape while airplanes can twist and turn but not change their wingspan's shape.

Lotus leaf effect (Super hydrophobic and self-cleaning surfaces),

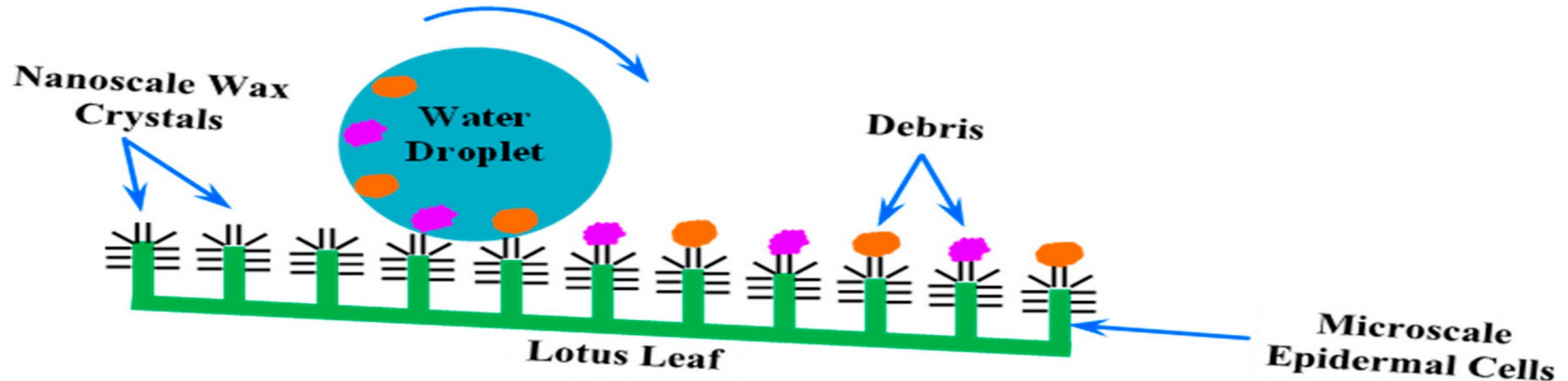
- The **lotus effect** refers to self-cleaning properties that are a result of **ultrahydrophobicity** as shown by the leaves of lotus flower.
- Dirt particles are picked up by water droplets due to the micro- and nanoscopic architecture on the surface, which minimizes the droplet's adhesion to that surface. Hence lotus do not get wet when rains
- This natural phenomena of lotus effect had inspired to develop ultrahydrophobic chemicals like perfluoroalkyl and perfluoropolyether



Mechanism of Lotus Effect

- The high surface tension of water causes droplets to assume a nearly spherical shape,
- Since a sphere has minimal surface area, and this shape therefore minimizes the solid-liquid surface energy.
- On contact of liquid with a surface, adhesion forces result in [wetting](#) of the surface.
- The cause of self-cleaning properties is the hydrophobic water-repellent double or two structure of the surface.
- Basically, the leaves had two levels of structures for hydrophobicity
- A microstructure level consisting of surface lumps and a nanostructure level formed by small hairs.
- Both systems are constituted by a waxy coating, which together makes the surface of a lotus leaf repel water and does not get wet (superhydrophobic surfaces).

- This enables the contact area and the adhesion force between surface and droplet to be significantly reduced, resulting in a self-cleaning process
- Hence, dirt particles with an extremely reduced contact area are picked up by water droplets and are thus easily cleaned off the surface.
- The lower epidermis (**Inner layer of leaf**) consists of convex cells covered with wax tubules and contains only few stomata. (**opening and closing structure of leaf**)
- The upper epidermis (**Outer layer of leaf**) structure consisting of papillae with a dense coating of agglomerated wax tubules, which is the basis for the famous



Applications of Lotus Effect

- Lotus a source of inspiration for innovative technological applications, including the building sector, with the creation of roofs and paints capable of self-cleaning.
- The Lotus effect in the development of paints that prevent corrosion of metallic materials. Such paints have excellent physical and structural properties and the incomparable Lotus-Effect technology.
- In this technology, the dirt slips away with the rain and the facade remains clean and dry for a long time.
- Development of Perfect insulators to prevent damage to electrical or electronic equipment by accidental contact with water.
- self-cleaning glasses installed in the sensors of traffic control
- Developed stain-resistant textiles under the brand name [nanosphere](#). Tests showed that clothes treated with NanoSphere technology allowed tomato sauce, coffee and red wine to be easily washed away even after a few washes.