Ocean Origins

TOPIC C: FORM AND FUNCTION
TEACHER RESOURCE

THE AQUARIUM OF WESTERN AUSTRALIA
SEA FOR YOURSELF

Background Notes

Our oceans teem with an amazing array of life and this marine life if full of surprising features; shells with detachable teeth that are soaked in venom and shot out like a harpoon to catch food, animals with teeth stronger than steel, the ability to create a stockpile of chemical weapons, bodies covered in microscopic teeth…all of these unique and amazing features are now being closely studied by scientists to develop new and improved products and medicines.

Using biology to benefit humanity is known as biotechnology. The oceans are considered to have limitless biotechnological potential because oceans themselves have the greatest extremes for temperature, light and pressure, yet marine life have worked out ways to survive and it is the study of these adaptations and the genetic diversity behind them that is generating exciting new products and discoveries.

MUSSELS AND SEAFOOD SUPERGLUE

- Mussels and barnacles are found attached to rocks, ropes, or jetty pylons, and use feather-like appendages to sieve out their food from the ocean.
- As they don't move around to catch their food, eating becomes a matter of real estate – or location! To get the best supply of food and oxygen, mussels need to be where there is lots of water movement from currents and waves. Crashing waves and currents mean great food but it also makes it hard to hold on.
- To stay fixed in one place, the mussels' adaptation is for a gland in their foot to ooze a sticky slime that hardens within one minute. In creating these threads, mussels take iron from the surrounding seawater and use it to join proteins together, linking all the molecules into a strong sticky mesh. Scientists have discovered that these threads can stick to anything – even Teflon!
- From this knowledge, scientists are developing new surgical adhesives (glues for operations), new ranges of dental glues for dentures and new cements for the building industry.
- The salinity of our blood is the same as seawater – so if glues can work in seawater they can work in our bodies.
- All these new inventions are fuelled by studies of the blue mussel – the same species that grows in Albany and Cockburn Sound. But wait, there's more!
- Current glues break down in seawater, so a mussel-based glue that works well in seawater is of huge interest for Navy Ships and oil rigs.
- Discovering how barnacles and mussels attach themselves is useful. If we know how they stick we can work out how to stop them from sticking. This has important implications for what they call anti-fouling – stopping plants and animals from attaching to the bottom of boats and other objects. Not only does this make boats go slower and use more fuel, but can introduce marine life from one part of the ocean to another, causing environmental problems.

ANCIENT SNAILS AND CREDIT CARDS

- The chiton is a marine mollusc found all along WA's coast that coats its teeth with a metal – that it makes itself – that is stronger than steel.
- Why? Chitons eat the algae that grows in thin layers on top of rocks in the intertidal zone. As it's hard to scrape all the algae off uneven rocks, chitons grind through the rock as they eat algae.
- Grinding through rocks requires hard teeth, so the chitons' adaptation is to coat their teeth in a mineral (iron oxide magnetite) that they manufacture.
- Chitons also don't just have one row of teeth like us. Instead, they have a tongue lined with teeth like an octopus and a garden snail. In chitons, the teeth are arranged in 40–120 rows that work like a conveyor belt with new teeth replacing old ones every two days.
- How this super-strong metal is slowly deposited on their teeth over these two days is what scientists are trying to discover – not only so they can recreate the production line to produce stronger metals for industry but because it would be handy for stronger strips on your ATM cards and other devices.

SEA URCHINS AND SHARP KNIVES

- Sea urchins eat algae that grows on rocks and, like the chiton, they will scratch off rock in an effort to try and get all the algae that they can.
- To keep their teeth razor-sharp, sea urchins have layers of hard then soft material.
- When the hard cutting layer is worn down and becomes blunt it breaks off. The softer layer wears down quickly revealing the next new sharp edge.
- By mimicking the layered composition of their teeth in the blade of a knife we could create a blade that always remains sharp!

SEA CUCUMBERS AND BRAIN SURGERY

- Sea cucumbers can switch their skin from flexible and floppy to stiff and more than 10 times harder due to an enzyme action and the way enzymes bind the protein fibres of their skin together.
- This reaction is the inspiration for a new material that can change dramatically from rigid to floppy when soaked in water. The material may be used for brain implants that will cause less inflammation.
- Scientists are also trying to apply this technology to bulletproof clothing application or clothing that morphs into armour! Just like the sea cucumber's skin, the clothing would be flexible and comfortable to wear but morph into armour (becoming rigid and protective) when necessary.

SEAWEED GELS

- Land plants have a cell wall that provides strength and rigid support and enable plants to stand up in the air. Under the ocean, this kind of support isn't needed. Instead, seaweeds need to be able to flow backwards and forwards with the ocean's waves and currents.
- The flexibility of seaweed is due to a unique gel-like cell wall.
- The three main gels developed from seaweed are used as thickening agents in hundreds of foods and pharmaceutical products.
- Seaweed gel: carrageenan
  - → Seaweed gel likes pulling water into it. If added to ice-cream, it soaks up all the water, making it thick and smooth instead of thin and runny. It also helps keep the water from forming ice when it sits in your freezer.
  - → This seaweed gel is also used in toothpaste, salad dressing, bread, beers, puddings, processed cheeses and dairy products.
- The seaweed gel, agar, is used to make gel capsules for tablets and vitamins and gel plates for culturing bacteria.
- A third type of seaweed gel is used in medical research and for separating DNA fragments.

JELLYFISH AND DNA RESEARCH

- When studying DNA scientists need to be able to track and mark individual genes within a DNA strand and watch how it divides and is moved around and between cells.
- Jellyfish have been around for millions of years; they have no brain, no true eyes and can't swim against currents – however, some can glow!
- Scientists have discovered that it is a particular protein that causes them to glow (bio-fluorescence).
- Proteins are small and can be attached to genes. By marking a gene with this glowing protein they can watch its development and movement throughout a living cell, giving an amazing insight into cell functions.

GETTING A CLOSER VIEW

- Being able to see into a living cell and watch what is happening wasn't possible for scientists studying human development until they discovered that;
  - → Sea urchin eggs and sperm closely match those of human eggs and sperm in size, and the eggs have clear membranes – so scientists can easily study the early stages of development.
  - → Zebrafish also have clear shells around their eggs. As the early stages of embryo development in fish and in humans are the same, scientists can study how our nervous system and spinal cords develop – by studying their development in the zebrafish.
- Scientists are getting a closer look at our nervous system by studying squid.
  - → Squid have the largest nerve cells on earth – making them easy to study! The nerve fibres themselves are the same as in humans, so knowledge learnt can be directly applied to humans.

SPONGES AND CANCER

- Clinical trials are underway for an anticancer compound from a Western Australian sponge.
- Sponges have been around for about 800 million years and are the oldest multicellular life form, so they have had plenty of time to evolve.
- Sponges are soft – they can't rely on a hard body for protection. They also live attached to one spot on coral reefs or jetties. Space is at a premium and everyone wants more, so sponges need to protect their turf!
- To stop themselves from being attached or grown on top of they have adapted an arsenal of chemical weapons to repulse their attackers. These chemicals are basically antibiotics that may be useful to us humans.
- The chemicals sponges secrete make them taste bad so that other animals don't want to eat them.
- Each set of chemicals can also do specific jobs such as stop the cells from another animal from dividing. This stops the sponge from being overgrown by a competitor but can also be used to stop cancer cells from diving and producing more.
- Scientists have also discovered that sponges generate specific chemicals to protect them from what's in the water. For example, if sponges are placed in front of a sewerage outfall they start to develop chemicals to protect them from diseases carried in our waste.
- This targeted response is also important for cancer as sponges may be able to develop a chemical that kills only damaged or cancerous cells without wiping out healthy ones.

CONE SHELLS – PAIN RELIEF AND BLOOD DISORDERS

- Cone shells are found from the North West cape around the top and over to Queensland. They inhabit shallow reefs, often burrowing under the sand.
- Cone shells feed at night and can swallow prey more than half their size thanks to deadly venom in their detachable teeth.
- Stockpiles of hard spear-like teeth are stored in the head of a cone shell – ready to be soaked in venom and shot out of a snout-like mouth. In just seconds, a venom-filled tooth pierces and poisons its prey, as the snout-like mouth contracts pulling the prey closer before widening to totally engulf it.
- In humans, the venom can be deadly and causes swelling and pain near the wound followed by muscular paralysis.
- The venom is very complex, each type of cone shell can have different venom and each venom contains at least 50 different toxins, amounting to a total of around 50,000 individual toxins. These toxins target the brain and nerves.
- By extracting particular toxins and altering the dose scientists have created a new drug that treats severe pain. This new drug is a thousand times stronger than morphine, which is a traditional painkiller.
- Other specific cone shell toxins are being studied to treat nearly everything from arthritis to cancer.

- While studying the cone shells' venom scientists also studied how the cone shell produces its venom. It was discovered that the production of venom was controlled by an enzyme and that this enzyme was very similar to the one that makes our blood clot. The difference was a shorter DNA sequence. The fact that a difference in DNA length resulted in either venom being produced or blood clotting, helped scientists to uncover the role of each section of the DNA sequence. This information is being applied to the treatment of blood disorders in humans.

CORALS – BONE TRANSPLANTS AND EYE IMPLANTS

- Corals are jellyfish-like animals that live together in a colony.
- Within their bodies, they store an algae that makes their food for them during the day and the corals themselves then use their tentacles to feed at night.
- The food made for them by the algae gives corals enough energy to create a calcium skeleton; it is this internal skeleton that is the basis of a coral reef.
- Because this hard skeleton is made by a living animal, molecules can move in and out of it very easily, much easier than anything we have invented so far.
- The skeleton of a coral is also full of tiny holes. When used as an eye implant in our bodies this enables the surrounding tissues to penetrate it, creating an extensive network of blood vessels, which allows muscles to attach enable a greater range of eye movement.
- Scientists have also discovered that different corals have different shaped pores and it is those that are hexagonal in shape are best for eye muscle attachment and growth.
- A coral's skeleton has a very similar chemical composition to human bone. Coral can thus easily become apart of the body's tissues and so coral bone transplants or eye implants aren't rejected by our bodies.

CORALS AND SUNSCREEN

- When it comes to sunscreen, the algae stored in the coral's body needs light to make food.
- To get the most amount of light corals live in shallow reef waters. This means that they are exposed to the sun for long periods of time.
- To stop itself from being burnt the coral's adaptation is a chemical compound that blocks UV light.
- This natural sunscreen has been code-named 855 and after 10 years of development is now in production. Look out for it in the sunscreens that you use.
- In studying coral sunscreen scientists discovered another adaptation; corals contain a bacteria that creates extra antioxidants when the coral is exposed to extra-strong UV light.
- As we age, our bodies don't make enough antioxidants and this results in ageing and leads to the development of disorders and degenerative diseases such as Alzheimer's and Parkinson's disease. What scientists are trying to do now is develop a pill that will do for us what the bacteria does for the coral, ensuring we always have enough antioxidants.

SHARKS – BATHERS

- The skin of a shark is covered in microscopic teeth called dermal denticles. These skin teeth are arranged into V-shaped ridges – these ridges of skin teeth give the shark's skin a rough feel (it was once used as sandpaper!).
- For the sharks, the roughness of their skin reduces friction when the shark glides through the water – making them quick and efficient swimmers. As water passes over the ridges in their skin it spirals in a microscopic vortex which decreases drag and turbulence, allowing the surrounding water to pass over the shark more effectively.
- The surface of Speedo's 'fast skin bathers' mimics the rough shark denticles to reduce drag along key areas of the body. The V-shaped denticle print helps the body slip through the water more smoothly.
- This design is so effective that at the Sydney Olympics 28 of 33 gold medals were earned in Speedo fast skin suits. They have been found to offer 3% less surface resistance and be 7.5% faster than all other suits tested.
- Designing bathers based upon shark skin was so successful that there was great controversy and debate over technology versus ability. The bathing suits have now been banned from professional competition.
- In the 1987 America's Cup race, the winning yacht 'Stars and Stripes' had shark skin-inspired ridges along its hull to reduce drag. The ridges were thought to have offered such an advantage that they were banned from competition from then on.
- The success of the design shows just how effective the application of ocean adaptations in everyday life/ situations can be!
- NASA now uses shark skin-inspired ridges on ships and aircraft. One day submarines may be totally covered in a shark skin style design as might the inside of water pipes so that water can travel faster through them.

SHARK TAILS AND POWER

- Sharks have inspired scientists to design underwater power generators.
- The tail shape of sharks, tuna and mackerel are up to 90% efficient at converting body energy into propulsion force.
- To turn propulsion from waves into energy that we can use, scientists at the University of Sydney designed a 15 m shark tail installed onto the seafloor.
- The idea is that water is forced past the tail by the tide, that force moves the tail and this is converted to energy.
- Near Garden Island (off Perth) there is another energy system being run. It also uses force from waves and currents to generate energy. It is, however, based upon the flexible back and forward movements of seaweed.

OCTOPUS – SEARCH AND RESCUE ROBOTS

- The latest designs for search and rescue robots have been inspired by a 'moonwalking' octopus.
- There is nothing hard in an octopus' body except its parrot-like beak. Any hole its beak can fit through is big enough for its whole body. The arms and body simply lengthen, becoming thinner and able to get through small holes.

- Robots have been unable to do this so far because scientists thought that they needed to have a rigid skeleton like ours to be able to walk and a rigid skeleton is no good for getting into small holes. If there has been an earthquake or a building collapse then this is exactly what a search and rescue robot would need to do – search through small holes in the rubble to penetrate the debris and look for signs of life.
- This stumbling block was overcome in 2005 when scientists discovered two species of octopus using their bands of muscles to 'walk' along the seafloor on two arms.
- Scientists discovered that the octopus was compressing one band of muscle to create a strong point or a leaver while the band of muscle after it stretches out.
- The octopuses were filmed walking by flattening part of their arm like a tank tread and rolling along the suckers, pushing the animal back. Then the other arm touched down and rolled along its suckers, pushing the octopus along. (The moves look like Michael Jackson's moonwalk.)
- A prototype of the octopus-like arm has been created – it's basically an artificial muscle – a tube with a spring inside into which an electric current can be put. The tube can shorten, lengthen and bend in all directions.

CUTTLEFISH – SUBMARINES

- The way a submarine moves up and down in the water is the same as the way a cuttlefish moves.
- The cuttlebone that you find washed up on beaches comes from the cuttlefish; it's their equivalent of the shell that surrounds a garden snail.
- A cuttlebone is really porous (full of tiny chambers). This is why it feels so light when you pick one up. These chambers are the secret to going up and down in the water column.
- If a cuttlefish wants to go up, it fills the chambers with air. If it wants to go down, it fills the chambers with water.

CUTTLEFISH – FINE ARTS

- Creating silver jewellery
  - → One side of a cuttlebone is very soft, making it easy to carve. There is also a layered texture to the bone which can resemble woodgrain or the rings of a fingerprint – making each casting original.
  - → Once the image is carved into the bone, you can pour molten silver onto the bone, then place it in cold water for the metal to cool. The cuttlebone is resistant enough to heat that it holds its shape when hot metal is poured into it.
- Ink
  - → India ink – the first mass-produced ink – comes from the cuttlefish and was widely used by artists in the past because of its dark reddish-brown pigment.
  - → The term 'sepia' is Latin for cuttlefish ink. It is used to describe a style of photos, a type of paint in paintboxes and is part of the scientific name for cuttlefish.

This list could be endless, so here is just one more of our favourites:

MANTIS SHRIMP AND CAR FRAMES

- To smash or spear their prey, mantis shrimp have two claws at the front of their body that move so fast they can create a shockwave.
- To punch so hard mantis shrimp have a special shock-absorbent core with a unique molecular structure.
- This structure stops small cracks from becoming full breaks.
- By copying the molecular structure of the mantis shrimps' claw, scientists hope to create stronger protective materials to keep us safe, such as explosive resistant material and stronger frames for cars.

Notes: