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# What Is Pressure?

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See also the activity, [Oh, The Pressure](#) on page 5 of *Ocean News Issue #1*

## Main Ideas:

Pressure equals force/area

## Objectives:

Students will:

- investigate pressure
- calculate the pressure exerted by their bodies on their feet
- learn that pressure = force/area

## Materials:

- a sheet of paper for each student lined in one centimetre squares (manually square off one sheet of paper, photocopy and distribute)
- bathroom scale, if students do not know their weights
- pencils
- high-heeled shoe

## Procedure:

1. Working in pairs, students can take turns tracing the outline of their partner's foot onto a squared paper.
2. By adding squares and estimating, determine the approximate area of the footprint.
3. Have students calculate the pressure exerted by each student when standing. [Their weight (in kg) divided by twice the area (in  $\text{cm}^2$ ) of their footprint.]
4. Have students calculate the pressure when they stand on one foot.

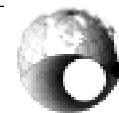
## Extension:

- Compare the pressure of a person standing in running shoes vs. a person of the same weight standing in high heels. What happens when someone in high heels steps on another person's toes?
- Have students calculate the water pressure (in  $\text{kg}/\text{cm}^2$ ) on a 1 cm x 1 cm area of each animal in the chart on page 4 of *Ocean News #1*, when the animal is at its maximum diving depth. (*Pressure in  $\text{kg}/\text{cm}^2$*  - Walrus, 10; Human, 10.7; Common Murre, 16; Bottle-nosed dolphin, 22; Emperor Penguin, 26.5; Weddell Seal, 66.6; Leather-back Turtle, 121.1; Elephant

*seal, 156; Sperm Whale, 225).*

- For a real challenge, have students figure out the theoretical weight of a person in high heels who exerts the pressure experienced by a sperm whale at its maximum depth.

# The Big Squeeze



## Materials:

- tall, transparent container (e.g. a beaker); water; balloon; heavy weight such as a diving weight ; a sheet of flexible rubber large enough to cover the mouth of the container; rubber band.

## Procedure:

1. Partially inflate the balloon and attach it to the weight.
2. Fill the container 2/3 full and place the balloon and weight at the bottom.
3. Fill the container to the brim. Place the rubber sheet over the mouth of the container and seal with a rubber band.
4. Push the rubber cover and observe what happens to the balloon. If possible, measure changes in the balloon size.

## Discussion:

What caused the balloon to decrease in size? (*Pressing the rubber caused a pressure increase around the balloon.*)

Where is the greatest pressure found in the ocean? (*at the bottom, in the deepest trenches*)

How might you keep the balloon from changing size as you push down? (*by continually adding pressurized air to the balloon or by making its walls rigid and capable of withstanding pressure*)

Why is it dangerous for scuba divers to hold their breath as they surface from a dive at depth? (*Expansion of air in lungs may cause rupture of lungs or lung tissues*)

Why is it difficult for you to sit at the bottom (3 metres) of a pool breathing air through a hose from the surface? (*The air coming in to your lungs through the tube is at one atmosphere while the pressure at the*

*bottom of the pool is 1.3 atmospheres. This creates a pressure differential, making it difficult to breathe.*)

Why do your ears hurt when you dive deep into the water? (*The air space behind the ear drum is at one atmosphere. As you dive down, pressure pushes the ear drum inward, causing pain.*)

What do SCUBA divers mean by the term "sinus squeeze"? (*Sinuses are air spaces around the face that can be difficult for divers to equalize on descent, giving rise to a painful "squeezed" feeling, alleviated by resurfacing.*)

## Extensions:

- Have students use the library to investigate the "bends" and how people get them.
- Have students research whether animal divers (see Ocean News page 4) get the "bends". Why or why not?

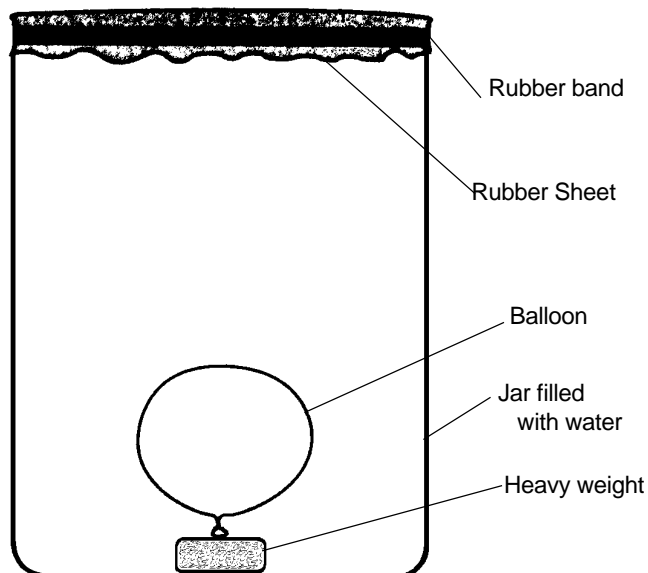
## Main Ideas:

At a constant temperature, the volume of a gas increases as pressure decreases. Conversely, gas volume decreases as pressure increases (Boyle's Law).

## Objectives:

Students will:

- learn about Boyle's Law
- understand what happens to air spaces, such as the lungs, when they are subjected to water pressure
- understand that scuba divers are able to dive to limited depths without injury
- investigate how diving animals deal with intense pressure





# Exploring Buoyancy and Gravity

## Main Ideas:

Objects are acted on by gravity and, in fluids, by buoyancy.

## Objectives:

Students will:

- explore the force of buoyancy and the force of gravity.

## Background:

If you try to lift someone in water they *seem* lighter. The *mass* of the person has not changed but her *weight* (her force of attraction to the planet) has. Water exerts an upward force called the *buoyant force*. All fluids exert a buoyant force on objects contained within them.

## Materials:

- a large plastic beaker or bucket filled with water
- a spring scale (preferably a scale in Newtons)
- string
- a stone or other weight

## Procedure:

1. Suspend the stone or weight from the spring scale and weigh it. (Weigh in Newtons (N) if possible, this is the standard unit for measuring force.) Record the weight.
2. Lower the weight into water and weigh it again. Make sure the weight *doesn't* touch the bottom of the beaker or bucket. Record the weight.
3. Calculate the difference in weight, in and out of the water. This number is the force of buoyancy on the object. (For example, if the weight weighs 6N out of water and 4N in it, the force of buoyancy is 2N.)
4. Try this experiment with other objects.

## Discussion:

What is the main force acting on the

object before it is put in water? (*force of gravity*)

In what direction does this force work? (*down*)

What is a second force acting on the weight when it is put in water (*force of buoyancy*)

In what direction does this force work? (*up*)

When an object floats, what is the relationship between the force of buoyancy and the force of gravity? (*buoyancy exerts a greater force*)

## Extensions:

- Investigate the force of buoyancy using other liquids. 1. Fill three glasses half full with water, concentrated salt water solution, and cooking oil. 2. Place a single rectangular block of relatively dense wood sequentially into each glass. 3. Compare the force of buoyancy of the three liquids. In which does the block float highest? Quantitative comparisons can be made with spring scale weighings, and by calculating the volume of block immersed in each liquid.

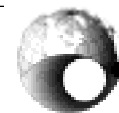
- Explain why ships float higher in salt water than in fresh.

- Explain what is meant by the expression, "the tip of the iceberg". (*Icebergs are frozen fresh water, which is less dense than the seawater. Also, water expands when it freezes, so a given volume of ice weighs less than the same volume of water. As a result, only a small portion of an iceberg will be seen above the surface - the 'tip'.*)

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# DIVING TECHNOLOGY

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## Ocean News Reference:

*Anatomy of a Sub, page 5;*

*Submerging Technology, pages 6 and 7.*

### Background:

For probing depths too great for SCUBA diving, scientists and technology engineers design and construct submersible vehicles capable of withstanding the tremendous pressures encountered in the deep sea.

Submersibles have many applications: scientific investigations; mapping and survey work; oil and gas exploration; defense; mining exploration and extraction; telecommunication cable retrieval; environmental monitoring; ground truthing of sonar estimates; inspection and cleaning of subsea storage tanks, sewer pipes and cooling tunnels of nuclear power plants; population estimates of harvestable species; and, observing the effects of harvesting processes on the ocean floor.

Many submersible designs use a sphere as the basic unit. This is the ideal shape for withstanding pressure since the force is distributed equally around the sphere. It is the favoured design for a deep diving sub with a small crew. For projects in shallow water carrying a large crew or a large amount of equipment, the favoured shape is cylindrical. A cylinder is more hydrodynamic as it travels through the water. It's a better shape for people and gear. Steel and aluminum are the most commonly used materials for sub construction, although other materials such as titanium, reinforced plastics, laminates, acrylic and even glass and ceramic are used.

One major limiting factor in submersible diving duration is the

power source. Pressure-compensated conventional batteries are generally used, making most subs slow, with a limited range and time underwater. Alternatively, the sub can be tethered to a surface ship by a cable with power. This limits the sub's range to the length of the cable.

Subsea vehicles need ballast to help them dive and resurface and for "trimming" the vehicle. A chamber for seawater ballast is common. Alternately, weights used to descend are dropped for the ascent.

### Activities:

*Sea vs. Space Travel*

*The Invention Convention*

*Step Back In Time*

*Take A Dive*

*Choose Your Subsea Vehicle*



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# Sea vs. Space Travel

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## Main Ideas:

Many similarities exist between subsea and space travel.

## Objectives:

Students will:

- investigate the similarities and differences between subsea and space travel.

## Materials:

- pictures of submersibles, diving suits, space craft and space suits

## Procedure:

1. Have students do library research to investigate the similarities and differences between subsea travel and space travel. Students could brainstorm in groups prior to doing the research.

Some ideas to consider:

- vessel shape
- how vessels must deal with pressure

differences between the inside and outside

- how vessels deal with temperature
- how space ships enter and exit the earth's atmosphere and how sub sea vessels descend and resurface
- vessel speeds
- power source
- life support systems
- vessel size
- communication systems
- scientific instruments
- navigation and location
- safety features



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# The Invention Convention

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## Objectives:

Students will:

- become familiar with the designs and uses of submersible vehicles.
- design a submersible

## Materials:

- photographs or drawings of submersibles used for deep sea study;  
- pages 4, 5, 6, 7 Ocean News Issue #1  
- model building materials such as juice bottles, wood scraps, bottle caps, straws; glue.

## Procedure:

1. Display photos of submersibles. Refer to the Ocean News articles on submersibles. Discuss the functions of the various parts. Have the students work in pairs or groups to design and possibly build a model sub.  
2. Have students explain different features of their subs in small groups. If

appropriate, have innovative designs presented to the rest of the class. Presentations should highlight the type of underwater work for which their vehicle is designed.

## Extensions:

- Try the activity: Make Your Own Sub (Cartesian Diver), page 5, Ocean News Issue #1
- Write a radio commercial or magazine ad for your invention. If a video camera is available, film a television commercial featuring your submersible invention. Explain why it is a better device for underwater exploration.

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# Step Back In Time

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## Materials:

Oceans News Issue #1, research materials, imagination.

## Procedure:

1. After reading and discussing “Diving Through History” (pages 2-3 of Ocean News) ask students to choose a particular invention to investigate at the library.

2. In small groups, have students role play as news reporters telling the world

about the success (or failure) of some new deep sea invention, or act as a diver just back from the inaugural trip in a new underwater vehicle.

## Discussion:

What limitations would early designers have experienced as they created their inventions? *Limitations of materials, such as wood, metal, glass and cloth that might have been available to many inventors; limits in understanding of the physics of diving.*

## Main Ideas:

Diving technologies have developed over the years as our understanding of physics and the limits of human beings has improved.

## Objectives:

Students will:

- learn about changes in diving technologies over the years
- “advertise” diving technologies to their classmates

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# Take A Dive

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## Background:

In 1960, Dr. Jacques Piccard and U.S. Navy Lieutenant Donald Walsh made the world’s record dive for depth in the Navy bathyscaphe, the *Trieste*. The Navy code name for the project deep in the Mariana Trench, about 250 miles southwest of Guam, was Project Nekton. Piccard and Walsh entered the *Trieste* on January 23 to make their historic descent, a brief synopsis of which is presented below. The men stayed on the bottom for 20 minutes where they saw two living creatures: a small red shrimp-like creature and a fish similar to a flounder. To surface, the *Trieste* released two tons of iron-pellet ballast from silos in the hull and began the ascent from the area they called the Challenger Deep (named after the British ship the *Challenger II*). The trip

back to the surface took 3 hours and 17 minutes. Piccard later described this historic voyage in the book *Seven Miles Down*.

## Materials:

- the following guided imagery account

## Procedure:

Lead students through a “guided imagery” of the dive of the *Trieste*. This vessel holds the record for the deepest dive in the world. In 1960, the *Trieste* descended 10,911 metres to the bottom of the Mariana Trench, then the deepest known place in the ocean.

Darken the room and, if possible, make it quite cool. Have students sit

## Main Ideas:

Diving is an adventure.

## Objectives:

Students will:

- imagine what it must have been like to dive to the deepest part of the ocean

*The quoted text in this activity is from: Diving for Science: The Story of the Deep Submersible by E.H. Shenton.*



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## Take A Dive, *Continued*

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quietly while you set the scene:

- you are inside the Trieste, very cramped (the sphere had a diameter of six feet), and cold
- your dive begins at 0823 when the tender ship, the *Wandank*, launches the *Trieste*. You begin to descend slowly. As you descend the ocean gradually gets darker and darker.
- by 0900 you have only reached 800 feet;
- at 1000 feet, there is only a faint trace of light filtering down from the surface. So far, you have seen some animals and minute specks of floating plankton through the 7-inch thick Plexiglass viewing ports.
- Soon, the vessel begins to pick up speed and you descend at a rate of 3 feet per second.
- after an hour of travelling you are at a depth of 3,000 feet
- at 0928, a slight leak is discovered and you must monitor it closely as you descend.
- by 1000 the *Trieste* is almost at 10,000 feet. The cramped cabin is very cold, but the leak has stopped. Nothing but blackness is visible outside of the ports.
- at 1100 the *Trieste* surpasses its own diving record of 24,000 feet made a few months earlier.

The following is the actual log recorded by Walsh. Continue the imagery by reading this to the students:

"Time 1206. We are passing 32,400 feet. A sharp explosive noise sounded outside, rocking the whole bathyscaphe [vessel]. We are trying to locate it. Jacques thinks it was one of the incandescent lights outside the port, but that doesn't seem to be it. Nothing else is affected and we continue to descend. All systems are normal."

"Time 1238. Six thousand fathoms [almost 36,000 feet!]. No indication of the bottom so far on the fathometer. Jacques has the bow light on and is periodically looking out, but there's no sign that we're getting close. We're moving slowly now because we've been dropping shot to slow our descent speed".

"Time 1258. We have the bottom in sight on the fathometer at 42 fathoms. Thirty-two fathoms. Fairly steep curve or slope here, 28, 25 fathoms, 24 — now we're getting a nice trace. Twenty-two, still going down. Twenty fathoms. Looks like we finally found it, Jacques. Sixteen fathoms, 14 fathoms. When we reach 10 fathoms we can start looking, can't we? Quite clear out there. Thirteen fathoms, 12 fathoms — 72 feet. Ten fathoms, making a nice trace now. Going right down. Nine fathoms, 50 feet. Any time now. Still going down, 8 fathoms, 7 1/2; nice trace there. Should be a very gentle landing the way that curve is. Going very slowly. May stop before we get to the bottom. About 5 fathoms—30 feet. You say you saw some little animals, Jacques? He says they're Medusa [jellyfish], or maybe red shrimp, about an inch in diameter. Four fathoms, 24 feet. Should see the bottom any minute now. Quite light outside with the vehicle's light reflecting off the bottom. We've landed! Fish — a fish about a foot long — at the bottom of the ocean! What does it look like, Jacques? He says it's like a sole—it *is* a sole. Does he have eyes or does he appear to be blind? Is he in the sand? Did he move away or is he still there?"

"We're at bottom. I think I'll turn off the fathometer here, Jacques. Check signals to the surface. Time 1306. Landed on the bottom, at 35, 800 feet!"

### *Discussion:*

Ask students how they felt during the dive. How must the actual passengers have felt?

Why do you think they went on this dive?

Why do you think they were so surprised to see life on the bottom of the ocean?

One year later on April 12, 1961, a Soviet cosmonaut became the first person to travel in space. Why do you think people remember that event, far more than this remarkable dive on January 23, 1960?

*(An excellent story to read or have students read is "Between Home and Abyss" found in Discover Magazine in December 1993. Also read sections of William Beebe's book, Half Mile Down.)*

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# Choose Your Subsea Vessel

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## Materials:

- Copies of information sheets "Some Features of Underwater Technologies" (photocopy next page);
- Ocean News Issue #1, pages 6-7.

## Procedure:

1. Have students review the details about each of the particular methods for subsea exploration.

2. Working in small groups, have students choose the most appropriate technology for the following tasks:

(Students should consider: goals of the mission; capabilities/limitations of the technology; cost (equipment and personnel); safety; size of crew required; speed and maneuverability of technology; ease of getting vehicle to exploration site.)

a. Fisheries staff would like to observe underwater trawling nets as they are dragged along the ocean floor. How do the nets catch fish? How many fish get away? The subsea technology used must travel very near to the net opening as it is dragged along.

b. A group of scientists would like to study an underwater volcanic eruption on the Juan de Fuca Ridge, 400 kilometres off the coast of southern Vancouver Island. The study area is 2.5 kilometres below the surface. The mission will be four weeks long and researchers need video footage and samples of water, sediments, animals and rocks.

c. A researcher would like to study food preference of sea otters that live in relatively shallow water.

d. A team of archaeologists would like to study the wreck of the *Valencia*, a ship which sank off of the west coast of Vancouver Island and now lies in 30 metres of water. This ship sank in an area renowned for its storms and rough seas which mariners call "The Graveyard of the Pacific." Archaeologists would like to examine both the inside and outside of the ship.

e. A team of oceanographers would like to survey and map an area of the ocean under the Arctic ice pack.

f. A contractor requires an underwater inspection of a natural gas pipeline, 50 -75 metres below the surface.

g. A sailboat owner would like to inspect the hull of her boat.

3. Have a class discussion on technologies chosen and the reasons considered.

## Extension:

- Have students imagine their own expeditions and determine appropriate technology for the task. Have them design new technology (or adapt existing methods) if an appropriate method does not exist.

## Main Ideas:

Different subsea vessels are available for a variety of subsea tasks

## Objectives:

Students will:

- identify a variety of methods for exploring the ocean
- determine capabilities and limitations of each method
- select appropriate technology for specific tasks

# Some Features of Underwater Technologies

## ROV - Remotely-Operated Vehicle

- needs a large support vessel with crew for launching
- a human controller on the support vessel operates the ROV with joystick and tv monitor
- usually use fibre optic cable as communication link
- power for the ROV is supplied along a tether to the support vessel (this allows unlimited endurance but limits speed and distance the vessel can travel from mother ship)
- range in weight from 50 kg to 8500 kg
- can dive to 3500 metres
- equipped with cameras, lights, sampling devices (for animal, rock, water and sediment samples), force-feedback manipulators (allow operators to feel the increments in force that the robot arm is exerting on an object), sonar
- high level of interaction between crew and vessel (i.e.. everyone can “participate” in the dive from the surface)
- theoretical unlimited endurance (crew can continuously be rotated)
- researchers are limited by what images they see coming from the site through the camera (i.e.. they are not actually there to observe things out of the view of the camera)

## AUV - Autonomous Underwater Vehicle

Similar to ROV except:

- not tethered to the surface (therefore not limited by length of a cable)
- radio-controlled
- battery powered (therefore limits endurance)
- can be set to follow specific instructions and is equipped with sonar to avoid unexpected obstacles and for mapping
- able to travel as much as 180 km from the mother ship

## SCUBA Diving

- relatively inexpensive
- most people can learn how to SCUBA dive
- freedom to swim underwater quite easily
- limits to range depending on fitness of diver and amount of air they are carrying
- most dives are 30 - 45 minutes in length
- limit of depth to about 30 metres

## One-Atmosphere Diving Suit

- divers can descend alone
- no need for decompression of diver — air is delivered at one-atmosphere pressure
- divers can explore to a depth of 300 metres
- can be operated tethered or untethered (untethered they can move with a thruster pack)
- require smaller support vessel and support crew than ROV, AUV or passengered submersible
- mechanical hands can manipulate quite small objects
- rotary joints give the diver close to a full range of motion
- can be transported by helicopter
- can assess entire scene — not just the position in front of a camera

## Piloted Submersible

- carries a crew (usually 1 pilot and 2 scientists)
- presence of passengers limits the length of a dive
- carry mechanical arms, sampling gear, cameras and lights
- not tethered to support ship
- requires a support ship to launch
- potential risk to passengers
- allows independent travel underwater and first-hand observation
- no need for decompression for passengers — air is delivered at one-atmosphere pressure

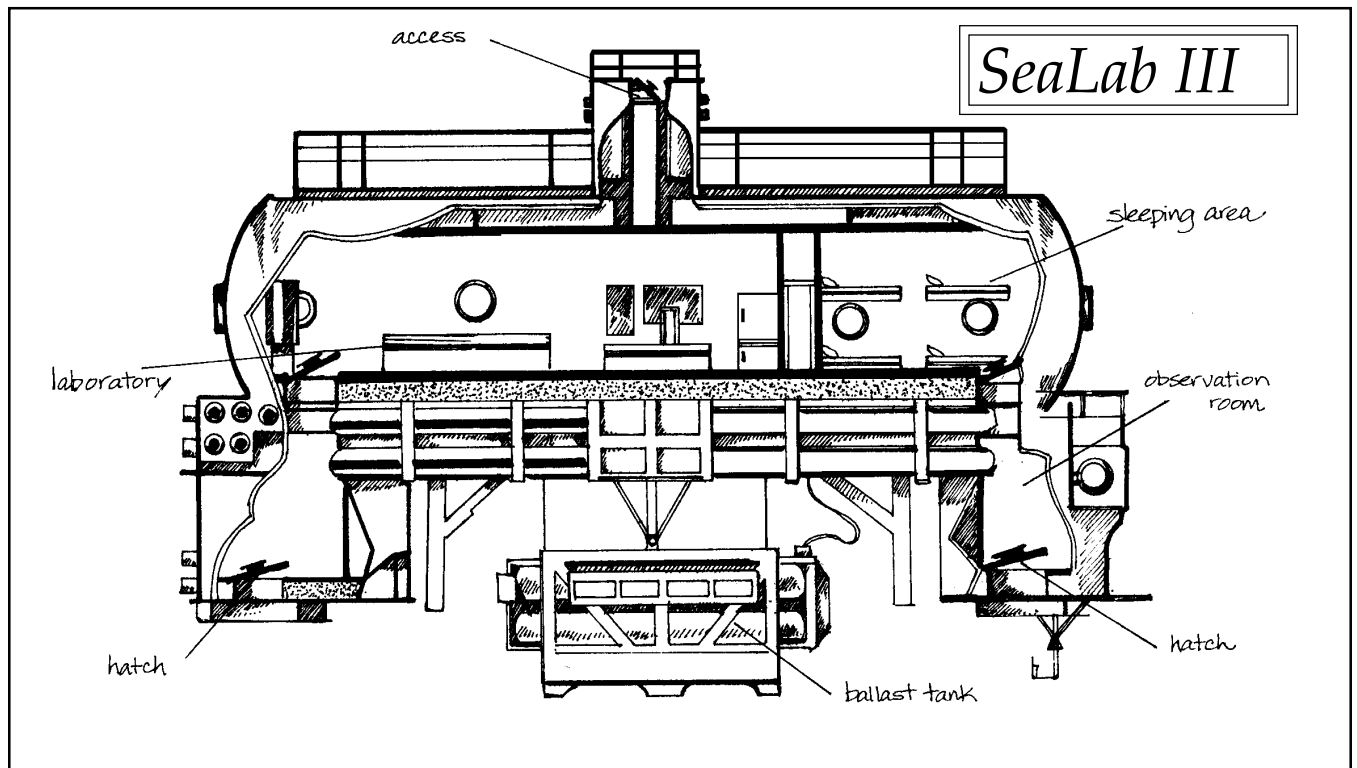
# UNDERWATER HABITATS



## *Background:*

While submersibles are great tools for allowing scientists and others to explore the deep sea for short periods of time, technological development in the past thirty years has included construction of undersea habitats which allow "aquanauts" to remain at depth in the ocean for periods of several weeks. In the 1960s and 1970s several habitats were deployed in the U.S. and were used for various research projects. Sealab, Tektite, Hydrolab, Aquarius, Medusa and LaChalupa are habitats that have been used in past years. Most of these habitats are operated by the U.S. Navy or NOAA (National Oceanic and Atmospheric Administration). All of these habitats are anchored to the

bottom, and provide living and working space for a crew of aquanauts. The entire habitat is filled with air at a pressure equal to the pressure of the surrounding water. Aquanauts can leave and re-enter the habitat to carry out projects. SCUBA gear may be required, or the divers can breathe through a hose from the habitat. Aquanauts cannot make emergency trips to the surface since their bodies are saturated with dissolved gases. To bring aquanauts back to the surface, the entire habitat can be sealed and raised as the interior pressure is slowly reduced to one atmosphere. Alternatively, special "transport capsules" can be used to return the aquanauts to the surface, leaving the habitat on the bottom for the next team to take over.





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# Deep Living

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## Main Ideas:

Underwater habitats provide research facilities allowing scientists to remain in the ocean for relatively long periods of time.

## Objectives:

Students will:

- investigate underwater habitats
- design their own underwater habitat

## Materials:

drawing materials, paper

## Procedure:

1. In partners or alone, have students design a deep-sea live-in research lab that would allow them to live for a month on the sea floor at 1000 metres.

2. Have students consider:

- access in and out of the lab at the surface and at depth
- work space
- living areas
- observation areas
- how does the lab get air and electricity?
- how do the aquanauts keep in touch with the surface?
- what type of research are the aquanauts doing?
- what would the aquanauts eat?
- how are the aquanauts transported from the surface to the lab

3. Have students give presentations in small groups on their research lab.

4. After the students give their presentation show them the picture of SEALAB III. Before entering SEALAB, the aquanauts have to spend time in a special chamber where their bodies grow accustomed to the air pressure they will experience inside the lab. This chamber is sealed and the aquanauts are transported to the lab in this watertight capsule. The capsule is fastened to SEALAB, and the aquanauts enter the

lab safely. Air and electricity are piped from a ship on the surface, and the crew keep in touch with a support crew via a radio. These crews stay in SEALAB for thirty days performing a variety of experiments including: rearing fish in cages, harvesting seaweeds and digging minerals from the ocean floor. Scientists are also experimenting with materials called semi-permeable polymers. These materials keep water out but let oxygen through. One hypothesis is that future aquanauts could live inside “bubble houses” built of this material.

## Extension:

- Have students prepare a research paper on actual underwater habitats. (Some habitats are: Conshelf, Sealab, Tektite, Hydrolab, Aquarius, Medusa and LaChalupa.)

- Students may enjoy reading *Sphere* by Michael Crichton which is set in an underwater habitat or you may wish to read from the book to provide setting for this activity.

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# PLATE TECTONICS

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*Ocean News Reference:*

*The Largest Jigsaw Puzzle in the World, page 8.*

## *Background:*

About 200 million years ago the continents were joined in a single landmass, called Pangaea (meaning all lands), surrounded by a universal ocean called Panthalassa. As Pangaea broke apart and the pieces drifted slowly into the positions they are in today, the Atlantic and Indian Oceans were formed. What remains of the ancestral ocean of Panthalassa is now called the Pacific ocean.

There are twelve large plates of crustal material and several smaller plates. These tectonic plates are all in slow, but constant, motion. Plates are created where lava wells up at spreading ridges or spreading centres, such as the Mid-Atlantic Ridge. Plates are destroyed, and re-melted, when one plate overrides the other, and then sinks back into the Earth's interior (specifically the asthenosphere.) With modern methods we are able to detect that plates move at a rate of about 3 to 8 centimeters per year. This is about how fast our fingernails grow. The Atlantic is expanding at this rate, while the Pacific is shrinking. Continental plates are made of less dense rock and "float" on the more dense oceanic plates. One researcher described it well when he said that "...ocean basins are not permanent features, and the continents are permanent although they may be torn apart or welded together."

Since the earth is a sphere, there are really only three ways the plates can

move relative to one another. They can collide, they can separate or they can slide past one another. Areas where plates collide and push against one another are called convergent boundaries. The tallest mountains in the world, the Himalayas, were formed when the edge of the Australian-Indian Plate scrunched up against the Eurasian Plate. When oceanic and continental plate boundaries collide, usually the oceanic plate dives beneath the continental plate and melts back into the earth's mantle. This is called subduction.

Boundaries where plates separate are called divergent. At present the Atlantic Ocean floor is opening up deep beneath the sea. As the two plates move away from each other the space between their ridges is filled with magma, molten rock from beneath the earth's crust. New sea floor is created at divergent plate boundaries in both the Atlantic and Pacific oceans. These mid-ocean ridges encircle the globe like the stitching on a baseball.

Boundaries where plates slide past one another are called transform boundaries. This lateral plate movement is what causes the earthquakes along the San Andreas fault, where the Pacific plate is grinding slowly northward past the North American plate.

## ***Activities:***

*An Earthy Mystery*

*Dance of the Continents*



# An Earthy Mystery

(This is a challenging problem-solving activity, Try it before discussing plate tectonics and preferably before students have read "The Largest Jigsaw Puzzle in the World - Ocean News, page 8).

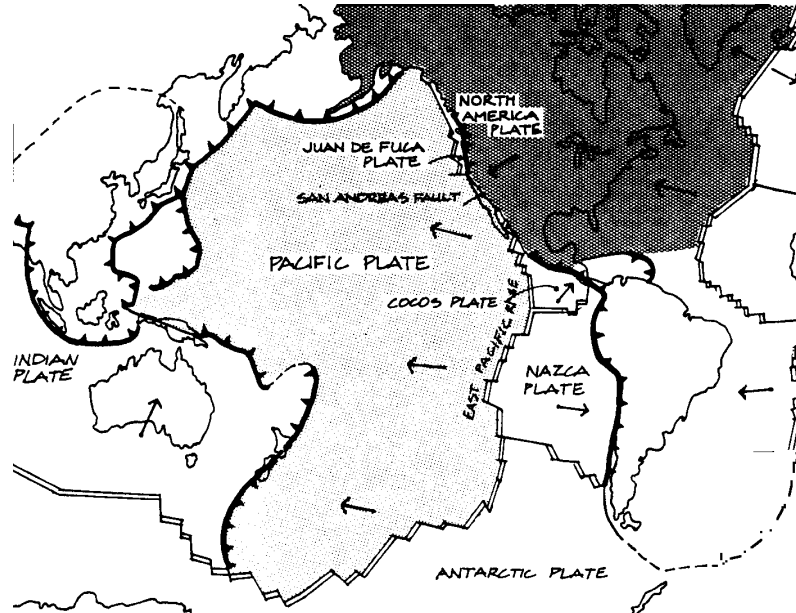
## Main Ideas:

Theories, such as those pertaining to plate tectonics and continental drift, often take years to formalize and are usually the result of a variety of independent discoveries coming together, like pieces of a puzzle.

## Objectives:

Students will:

- discover the variety of independent studies that came together to form the theories of plate tectonics and continental drift.



## Background:

Over the years, a variety of information has come to light, all of which has been amalgamated to form the theories of Continental Drift and Plate Tectonics. This activity gives students a chance to use the same pieces of information to make their own hypotheses ('theories') for continental drift and plate tectonics.

## Materials:

one set of puzzle clues (copies of pages 40, 41) for each group of students.

## Procedure:

1. Divide the class into groups of 4.
2. Give two clues to each student. Working alone, each student should read the clues and become prepared to discuss the information and what it implies about the history of the earth.
3. After an initial thinking time, have the

groups discuss each piece of information and then work together to develop a well-reasoned hypothesis to explain all of these clues. The group should be prepared to report back to the large group on their hypothesis and its rationale.

4. In the large class, discuss the hypotheses, noting differences in the rationale of each group.

## Discussion Points:

- What are some plausible reasons for the fossils of *Mesosaurus* to exist only on the west coast of Africa and the east coast of Brazil?

- What do you think is happening at rift valleys?

- What do you think this scientist meant when he wrote: "... ocean basins are not permanent features, and the continents are permanent although they may be torn apart or welded together .." Give some reasons proving or disproving what he said.



- Where are the youngest rocks in the oceans found?
- In 1915, Alfred Wegener hypothesized that the continents all were once joined together. He couldn't prove however, *how* the continents moved apart and most of his colleagues dismissed his idea. How did the continents move apart?

### Teacher Notes:

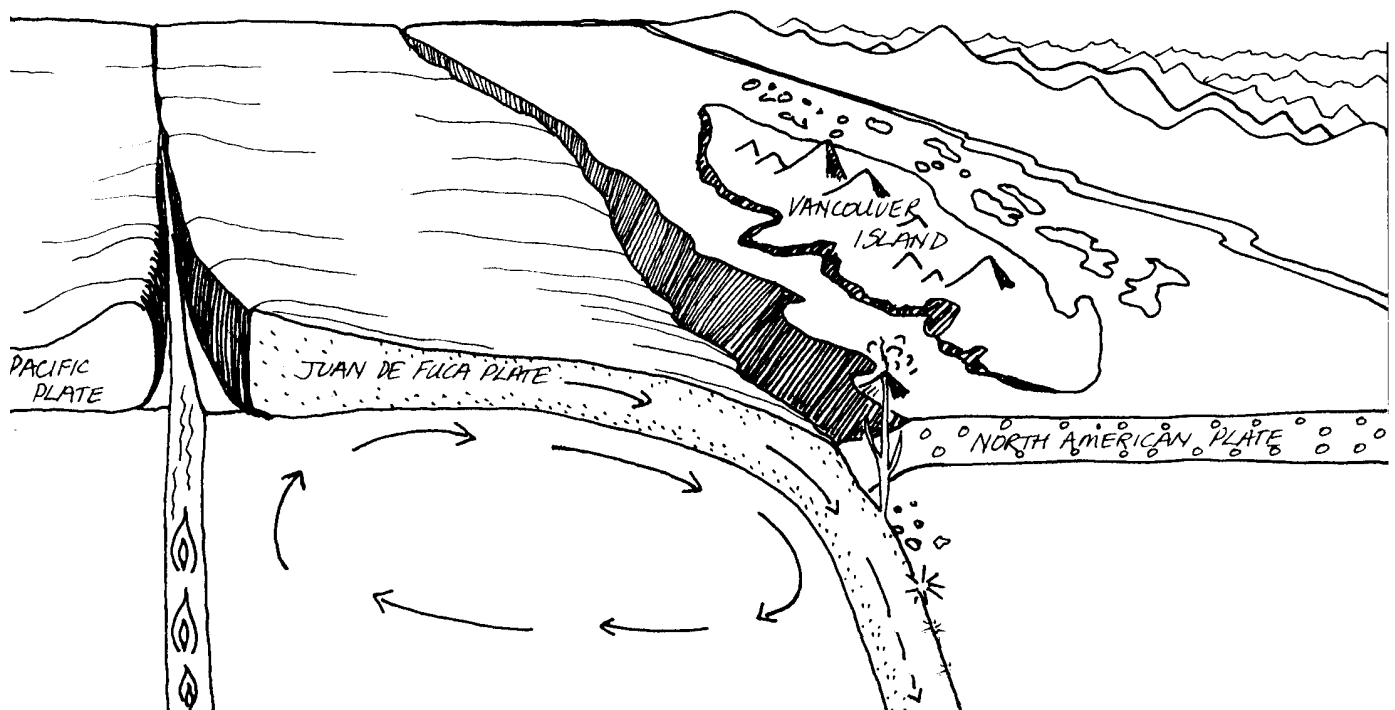
Huge Underwater Mountain Ridges: The Mid-Atlantic Ridge is typical of mid-ocean ridges, effectively a double-crested range with a central or 'rift' valley. Rift valleys are seafloor spreading centres where molten rock rises to the surface to create new oceanic plates. Plates are subsequently "consumed" at ocean trench subduction zones.

Convection currents: Hot magma tends to rise from the molten center of the earth towards the crust at the spreading centres — that "valley" in the centre of ocean

ridges. (This also explains why scientists found very hot temperatures in the middle of ocean ridges.) Cooled mantle materials tend to sink back down into the trenches. These are the convection currents in the earth. These powerful currents of rock broke up the original continent. Where the convection currents break through the crust they form the mid-ocean ridges. At the ridges, the sea floor is continuously created as magma emerges from the mantle and cools.

Palaeomagnetism: This is now seen as evidence which confirms the hypothesis that seafloor spreading is occurring, and new oceanic crust is being produced at midocean ridges. The new earth crust which forms from magma oozing up and cooling today is magnetized with the same polarity as the earth's present magnetic field. "Zebra stripes" of reversing polarity are identical on either side of spreading centres.

Earthquake Areas: The famous "ring of fire" is a ring of area, rimming the Pacific, that has a high concentration of earthquakes and volcanoes. This ring coincides with the plate boundaries.



### Jigsaw Puzzle-Like Maps:

As long as maps have existed, people have noticed the match-up between the bulge of South America and the dent of south-western Africa. In fact, if you look at a map of the world, you will notice that the shores on the western side of the Atlantic Ocean (North, Central, and South America) seem to match with the shores on the eastern side of the Atlantic (Europe and Africa). How can you explain this match?

### Fossil Evidence:

Researchers have found 270 million-year-old fossils of the extinct reptile, *Mesosaurus*, only in Brazil and Africa. Fresh water reptiles quickly die in salt water, so *Mesosaurus* could not possibly have survived a swim across the Atlantic Ocean. How did it come to live in two such widely separated areas?

### Huge Underwater Mountain Ranges:

Many echo sounding readings were taken during World War II by navy ships searching for enemy submarines. After the war, several scientists looked at all the Atlantic Ocean readings and developed a map of the ocean floor. They were very surprised to see a huge mountain range over 14 000 kilometres long with peaks that jutted up 3000 metres from the ocean floor. This mountain range, extending up the middle of the Atlantic, became known as the mid-Atlantic ridge. In a way it is not a single range of mountains but rather a double range of mountains with a valley running the entire length of the range separating the two series of peaks. Nothing quite like this exists on the land, although an area in Africa called the African Rift Valley has many similarities. Also most of the rest of the Atlantic ocean floor is relatively flat and deep without many other such distinct features. Can you explain this?

### Dating Rocks:

Rocks from any part of the world can be dated with radio-isotope techniques. The method tells us when the rock turned from a liquid to a solid - when it was cooled to become a rock from a liquid magma.

Dating rocks from the ocean floor revealed some interesting things. For one, the youngest rocks on the floor of the Atlantic Ocean come from a huge mountain range running up the middle of the Atlantic called the mid-Atlantic ridge. Rocks right in the centre of this range (in a valley found there) are, in fact, the youngest or most recently formed rocks, a matter of thousands of years old. If you go away from the centre of the range, in either direction (West or East) the rocks get older and older. The pattern is very similar in either direction - 200 kilometres to the East of the ridge rocks are about as old as are rocks 200 kilometres to the West - perhaps only 6 million years.

It is surprising that such recent rocks are found here and that they have been produced in this pattern. Can you explain this?

### Earthquake Areas:

Earthquake studies show that there are two major places where earthquakes are likely to occur: 1) in the deep ocean in areas with mountain ranges with a valley in the centre – now called mid-ocean ridges, and 2) along certain continental shores such as the shores of North America where there are volcanoes and major fault lines such as the San Andreas Fault or where there are mountain ranges such as the Andes of South America. Few earthquakes seem to occur in the middle of the continents or in the flat ocean basins (although they are occasionally known).

What do earthquakes reveal about the earth, and what might explain their distribution?

### Paleomagnetism:

The earth has a magnetic field that runs north and south. It is believed that the core of the earth is the source of this magnetism.

Melted rocks become magnetized when they cool. Researchers discovered, by looking at the magnetic fields in rock samples, that the earth's polarity reversed between north and south many times over millions of years.

In the 1960s, studies of magnetism on the ocean floor showed a sort of zebra-stripe pattern of north-pointing and south-pointing magnetic zones across the entire Atlantic. Zones of magnetism ran parallel to a giant underwater mountain range called the mid-ocean ridge (it was in the middle of the Atlantic). The pattern of magnetic zones found on the ocean floor to the East of the mid-ocean ridge was almost identical to the pattern found on the ocean floor to the West of the mid-ocean ridge. Over long periods of time the earth's magnetism must have changed many times as captured in the rocks, but what could explain this pattern?

### Convection currents:

If you heat water in a beaker with a hot flame, you will notice currents flowing in circular patterns as the hot water rises up and is then cooled at the edges of the beaker. The cool water sinks. This circular current pattern is called a 'convection current'. Convection currents seem to occur whenever there is fluid heated in one region and cooled in an adjacent region.

Studies of the earth, and the presence of volcanoes, indicate the earth is very hot below the surface, hot enough to be a liquid. Thus, we can speculate that below the surface of the earth there are convection currents of hot fluid magma. These convection currents would likely move rock laterally as well vertically, just as water moves across the beaker as well as up and down. Can you speculate what convection currents **inside** the earth may do?

### Hot Centres:

A huge underwater mountain range extends the entire North-South length of the Atlantic Ocean. Since it is more or less in the middle it is called the Mid-Atlantic ridge. Studies of rocks and sediments on the ocean floor have revealed that the floor of the Atlantic is not of even temperature across the ocean. Rocks in the centre of the mid-ocean ridge are much hotter than sediment and rocks in all other parts of the Atlantic.

Detailed studies of the depth of the ocean floor indicate there is a valley along the centre of the mid-ocean ridge mountain range. It is here that the higher rock temperatures are found - and not on the outsides of the mountains.

What might explain these higher temperatures?



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# Dance of the Continents

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## Background:

In this activity students make a 'flip book' to show movement of the continents from the ancient times of Pangea to the present. You may wish to show overheads of more detailed views of ancient continental arrangements to start off the activity.

## Main Ideas:

Continents have moved significantly across the face of the earth through geological time, a process called continental drift.

## Objectives:

Students will:

- see how the continental plates have shifted over geological time from the time of Pangea to the present.

This activity can form an excellent link to studies of extinct animals such as dinosaurs, to studies of evolution, or to studies of the geography of the present day world with its relatively widely-separated continents.



## Materials:

Three copies of the attached pages of continental drift images.

Stapler

## Procedure:

1. For each motion booklet, three copies of each "frame" on the following pages are required.
2. Cut out all the frames and order them from past to present.
3. Staple the booklet on the left side.
4. Flip the pages quickly and watch the pictures.

## Discussion:

How do the continents actually move?

What happens when the plates bump against one another?

## Extension:

Cut out an extra set of the pictures. Cut out each frame and black out the date. Mix up the frames. Have students put the frames in the right order to illustrate the formation of present-day continents?

Show the videos "Moving Plates and Continents" and "Continental Drift" available from the National Film Board of Canada (NFB 113c 0181 176)

*Adapted with permission from Science Is...: A Source Book of Fascinating Facts, Projects and Activities, Second Edition, by Susan V. Bosak. Copyright 1991. 515 pages. Richmond Hill, ON: Scholastic Canada Ltd., (416) 883-5300.*



*210 Million Years Ago*



*130 Million Years Ago*



*180 Million Years Ago*



*100 Million Years Ago*



*150 Million Years Ago*



*90 Million Years Ago*



*80 Million Years Ago*



*40 Million Years Ago*



*60 Million Years Ago*



*20 Million Years Ago*



*50 Million Years Ago*

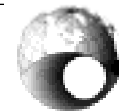


*Present*

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# SATELLITES

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*Ocean News Issue #1 Reference: Satellites, Subs and Sea Squirts, page 12.*

## *Background:*

The first satellite into space was SPUTNIK 1, launched by the Russians in 1957. It was followed by several United States satellites and in 1962 by ALOUETTE 1, Canada's first satellite. By 1972 Canada launched ANIK 1, its first domestic communications satellite. There are now many satellites in the ANIK series, used for search and rescue operations, mobile phones and TV and radio communications.

Satellites can also be used for remote sensing. Several types of imaging devices are used to make observations of the earth's surface. A camera is one type of imaging device. Relaying repeated photographs of cloud patterns as it orbits the Earth, a satellite can beam information used to produce the moving cloud pictures seen on TV weather reports. Satellite cameras are also used to track the movement and melting of ice floes in the Arctic and Antarctic and to predict weather patterns including storms and hurricanes.

A satellite can be launched into space in either a **Low Earth Orbit** or a **Geosynchronous Orbit**. Satellites used for search and rescue and for radio and television broadcasting are in geosynchronous orbit. This means they are orbiting around the earth at the same rate as the earth is moving. At the equator, for example, a geosynchronous satellite travels at a speed of about 11,060 kilometres per hour at a height of 36,000 kilometres. These satellites are now used routinely by ships at sea and smaller fishing vessels along the coast to determine their exact latitude and longitude. By monitoring position in

relation to a satellite every hour and marking the position on a marine chart, a skipper can plot the vessel path through the sea, miles from any shore.

PALAPA is a geosynchronous satellite system which has been positioned over Indonesia since 1976. Imagine the difficulty of providing TV to people living on the 13,667 islands of the Indonesian archipelago. The PALAPA satellite provides radio and television programs, just as our satellites do in remote areas all across Canada.

The satellites that can be seen travelling across the night sky are in Low Earth Orbit. They are from 200 to 1000 kilometres above the earth's surface, travelling around the Earth in 1.5 hours at speeds of 28,000 km per hour. They are constantly receiving information from the land or water beneath them.

Imagine you are in a car, looking out a side window. You blink your eyes every second and take a picture every time you blink. This is similar to what a satellite is doing as it orbits the Earth. Satellite images of sea surface height or cloud patterns or even of the amount of chlorophyll in the sea can be picked up on a specialized satellite antenna, like an eye in the sky. This image is converted to a picture and is beamed back to Earth using radio waves.

## *Activities:*

*Simulate A Satellite*  
*Colour Your Ocean*

## **Vocabulary :**

**chlorophyll** - a series of pigments that produce the green colour of plants; they absorb blue-green and red light, and reflect green light and play a basic role in photosynthesis.

**geosynchronous orbit** - an object such as a satellite, that moves at the same rate as the Earth, so that it appears to be standing still.

**low earth orbit** - an orbit 200 to 1000 kilometres above the Earth's surface.

**photosynthesis** - the use of the energy of sunlight to make carbohydrates from carbon dioxide and water by absorbing light energy and converting it to chemical energy.

**phytoplankton** - plants that drift in the sea

**primary production** - the amount of food manufactured from inorganic substances by photosynthesis

**satellite** - an object that orbits around a larger body (eg. the moon is a natural satellite of the Earth)

**zooplankton** - animals that drift in the sea



# Simulate A Satellite

## Main Ideas:

- the closer a satellite travels to Earth, the faster it must travel to stay in orbit
- there are two types of satellites: those in low earth orbit and those that are geosynchronous

## Objectives:

Students will:

- distinguish between geosynchronous and low-earth orbit satellites
- understand the relationship between the altitude and the velocity of a satellite

*This activity was adapted from: NSTA Galapagos JASON Curriculum © 1992. National Science Teachers Association, 1840 Wilson Boulevard, Arlington, Virginia 22201-3000.*

## Background:

As a satellite circles the Earth, the Earth's gravity keeps the satellite from flying off into space. After an initial push into space by a rocket, the satellite's orbital speed keeps it in space. The force of gravity is always working on the satellite and the speed must be maintained at a rate that prevents gravity from pulling the satellite closer and closer to Earth. The closer a satellite is to the surface of the earth the faster it must travel to stay in orbit. The farther away from Earth the satellite travels, the weaker the Earth's gravitational pull, so the orbiting speed can be slower.

A satellite at 320 km above the Earth must travel at about 22,000 km/hr to stay up in orbit. At this speed the satellite orbits faster than the Earth's rotation and appears to be moving around the Earth relative to a stationary observer on Earth. However, at an altitude of about 36,000 km a geosynchronous satellite appears to stand still but is actually moving 11,000 km/hr. At that speed and altitude the satellite makes one orbit of the earth every 23 hours and 56 minutes. It moves along in synchrony with a stationary observer on Earth.

## Materials:

- small Nerf ball;
- about 1 meter of elastic cord.

## Procedure:

1. Tie the elastic cord around the ball securely, so the ball won't fly loose.
2. In a large, clear space, have a volun-

teer swing the ball "satellite" around on the cord above her head. Try to keep the ball horizontal. Have the class observe the speed of the ball. The speed can be calculated by measuring the orbit diameter, calculating the circumference travelled, and dividing by the amount of time taken to make one orbit. Orbit time can be determined from a timing of several swings around the orbit, divided by the number of swings.

3. Wind up one third of the cord and repeat the experiment. Wind up the cord again so only a third of the original length remains and repeat.

4. Ask students what difference they observe. (*The closer the ball is to the pivot point—the swinger—the faster it has to move to stay horizontal.*)

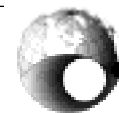
## Discussion:

The student holding the cord represents the Earth. The cord represents earth's gravitational pull. The ball is a satellite, constantly orbiting Earth. The closer the satellite is to the Earth, the faster it must move to stay in orbit. The nearer the Earth, the stronger the gravitational pull. Consequently, the satellite must travel faster to avoid falling to Earth.

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# Colour Your Ocean

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## *Background:*

Satellites, aircraft and ships are all used to gather data on ocean production and pollution.

The ocean food chain starts with small single-celled plants, called phytoplankton, that drift in surface waters. Phytoplankton are eaten by zooplankton (drifting animals) or by animals that filter feed. Zooplankton in turn are eaten by larger animals like shrimps and juvenile fish, which are then eaten by still larger animals.

Since phytoplankton are the first link in this food chain, they are the primary producers. On days with bright sunlight and lots of nutrients in the water, billions of phytoplankton cells grow and reproduce rapidly, or “bloom”, in the surface water. From space, satellites can detect the colour of large patches of primary producers.

Satellites may also monitor ocean pollution. Dark green sea water means an abundance of chlorophyll which means healthy plants, while light or dark blue sea water usually means clear, pure water. Phytoplankton often turn yellow when they die, like the leaves of trees. Thus, colours of yellow-green may mean plants are dying, either from natural causes or from pollution. Brown colours seen by a satellite are commonly caused by sediment runoff, but brown can also indicate dissolved organic pollutants.

Once the satellite computer has accumulated data on ocean colour by monitoring very small changes in shades of blue, yellow, brown and green, this information is beamed to a computer on earth. To make it easier to

see patches of colour, the computer is programmed to convert data to bright, rainbow shades.

Colour-coded ocean maps show the highest concentrations of chlorophyll in reds, yellows and oranges — the hot spots of phytoplankton blooms. Lower chlorophyll concentrations, which happen as plants die or become polluted or are hidden by sediments, are shown on colour-coded map in shades of green, blue and white. The lowest chlorophyll concentrations, where pure ocean water is all the satellite eye can see, are shown in shades of deep blue and violet.

One particularly productive area in British Columbia is at the mouth of the Juan de Fuca Strait where a huge gyre, called the Juan de Fuca Eddy, brings nutrients up from a deep canyon and spins them into a circle.

Between 1978 and 1986 the US satellite NIMBUS 7 collected phytoplankton data with a sensitive antenna called the CZCS (Coastal Zone Colour Scanner). It could measure an area of one million square kilometres in two or three minutes. Each pixel (box) of colour information corresponded to an area of one square kilometre (about the size of a square measuring 10 x 12 city blocks).

## *Materials:*

- satellite pictures (from oceanography text books or Fisheries and Oceans brochures) that measure a variety of ocean features and/or copies of the map in this activity coloured as indicated;
- copies of the two charts in this activity for each group of students

## **Main Ideas:**

- satellites are capable of recording a variety of phenomenon in the ocean including: chlorophyll concentrations, temperature, sea surface height, sea ice data, etc.

## **Objectives:**

- Students will:
- learn that satellites are used to gather a variety of oceanographic data
  - learn about primary productivity in oceans off the West Coast of North America.



*Procedure:*

1. Distribute satellite maps or photos of ocean productivity, temperature, or other data — or have students colour in photocopies of the map below. It is important to emphasize what information is indicated by the colours in each map/photo. Distribute the tables of information on satellite ocean monitoring to each discussion group. Students should work in groups to interpret the meaning of all the features they see on their maps/photos.

*Discussion:*

The following focus questions are typical of the types of questions needed to help guide the activity.

Where is primary production (growth of plants) the highest? Why?

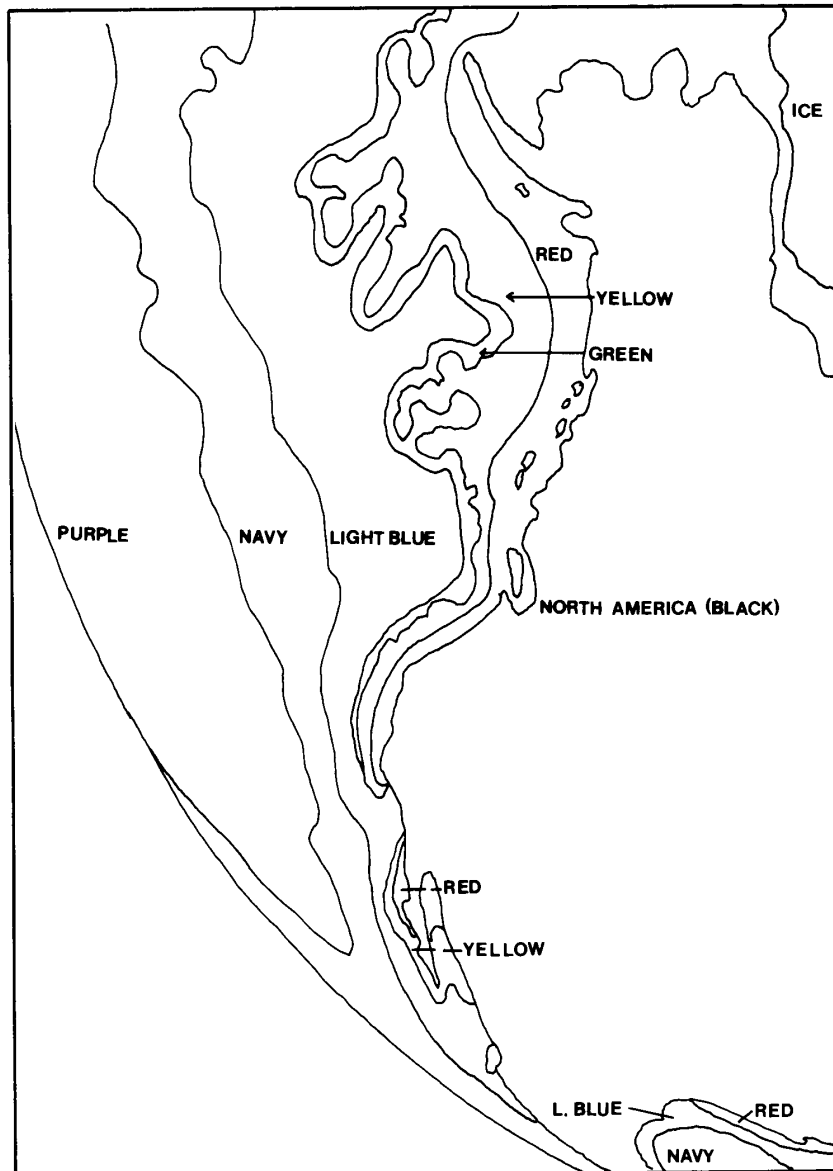
Where is production the lowest? Why?

What could these maps of primary productivity be used for?

Occasionally there are “spots” of high productivity far off shore, surrounded by areas of relative low productivity. What could these be?

What are some consequences of changes in phytoplankton abundance (i.e. seasonal nature of phytoplankton production or loss of primary producers due to pollution, etc.)?

**Map of the Pacific Ocean and Western North America showing regions of ocean productivity derived from satellite data averaged over 180 days.**



## Table of Ocean Features Frequently Measured by Satellites

**Sea Surface Winds** - Wind speed and direction can be measured. This calculation is important to oceanographers since winds drive waves and affect ocean currents.

**Ocean Wave Height** - Wave height is closely related to sea surface winds. This information is important for ships and for ocean drilling and mining operations.

**Sea Surface Temperature** - Temperature measurements are important for detecting the boundaries of oceanic fronts (similar to weather fronts in the atmosphere.) Sea surface temperature data provide information on large-scale currents, and on smaller current meanders and eddies.

**Sea Ice Data** - The amount and extent of ice coverage is important for commercial and military operations in icy waters. Measurements of ice sheet elevations are used as determinations of whether polar ice caps are growing or melting, and therefore whether the climate is cooling or warming.

**Sea Surface Topography** - The sea surface has hills, valleys, and bulges associated with variations in gravity from place to place on the sea floor. Measurements of sea surface height provide information on seafloor bathymetry (how the ocean bottom looks).

Over large sea floor masses like the mid-ocean ridges, gravity is greater than over deep-ocean trenches. The sea surface rises as much as 5 millimetres over a ridge and may be depressed by as much as 60 millimetres over a trench. Large scale ocean currents also cause bulges or depressions in the sea surface height; ocean currents are deduced from their influence on sea surface topography.

**Ocean Colour** - These measurements provide information about water clarity. The clearest mid-ocean water is deep blue, and algal-filled coastal waters are yellow-green. By setting instruments to wavelengths associated with chlorophyll pigments, chlorophyll concentration is calculated and phytoplankton productivity is deduced.

*This chart is adapted from information in Satellite Oceanography: Steps for Developing a Cutting-Edge Curriculum by E. Barbara Klemm in Current: The Journal of Marine Education. Volume 11, Number 3, 1992.*

## Ocean Features Studied From Ocean Colour Data

**Upwellings** - Upwellings are the vertical currents that carry nutrient rich waters to the surface. They are caused by winds that set surface currents in motion, pushing water away from an area and making a slight depression in the surface of the ocean. Cold, nutrient-rich water flows upwards to fill the depression. The nutrients promote rapid growth of phytoplankton. Because of the abundance of food, areas of upwelling are often very rich fishing grounds.

**El Nino events** - Periodically, prevailing wind conditions and cold upwellings cease. Ocean surface temperature increases, and phytoplankton in the sunlit zone quickly deplete available surface nutrients. Scientists have dubbed the cessation of the winds and upwellings, and the warming of the water, as an El Nino event.

**River Discharge** - Suspended material from rivers is highly reflective and observable in the visible spectrum. Future satellite studies are planned to determine whether the nitrates and phosphates produced from agricultural and urban sources and discharged into coastal water enhances primary production. Such studies will

require understanding of nearshore circulation and how plumes form, mix with water and then disappear.

**Seasonal phytoplankton blooms** - During the winter, ocean surface water becomes so cold that it sinks, causing vertical mixing of waters. Deeper waters rich in dissolved nutrients are mixed with near-surface waters that are depleted of nutrients. When daily sunlight increases in the spring, conditions favor such rapid phytoplankton growth that a "spring phytoplankton bloom" is said to occur. The spring bloom is a major oceanic event and may play an important role in the global carbon cycle.

**Ocean boundary currents and eddies** - In these areas, isolated bodies of water meet and mix. Each water mass contains different living organisms and differs in temperature, salinity and other qualities, including colour. Ocean colour images provide information on how eddies and streamer currents form and how they change over time. This knowledge is important in understanding the processes that enrich offshore waters with nutrients and plankton.

*This chart is adapted from information in Satellite Oceanography: Steps for Developing a Cutting-Edge Curriculum by E. Barbara Klemm in Current: The Journal of Marine Education. Volume 11, Number 3, 1992.*