Appendix A

STSE

Important Notes

1. These STSE modules are intended for teacher reference. Each is designed to target specific outcomes within Grade 7 Science. It should be noted that the questions, extensions, activities, and further research suggestions associated with each module are NOT mandatory. They can be used at the discretion of the teacher.

2. These STSE modules and the associated supplements can be found at www.gov.nl.ca/edu/k12/curriculum/guides/science/index.html#intermediate

The Two-Centimetre Forest

Outcomes:

1. Describe how our need for a continuous supply of wood resulted in the development of silvaculture practice. (112-3)
2. Make informed decisions about forest harvesting techniques taking into account the environmental advantages and disadvantages. (113-9)
3. Provide examples of how our understanding of boreal forest ecology has influenced our harvesting practices identifying the positive effects of these practices. (111-1, 113-1)
4. Identify various science- and technology-based careers related to forest management and harvesting. (112-9)

Introduction

After a hard day at school, it's good to go home and relax, put your feet up on the coffee table and haul out your favourite comic book. It may be raining or snowing outside, but you live in a sturdy home with a solid roof over your head. But have you ever stopped to wonder how that comic book got into your hands? How about the coffee table or the warm and cozy home you live in? All of these things, and many other products we use everyday, are made from wood.

Wood is one of the most versatile products on our planet. We can burn it, bend it, cut it, carve it, paint it, or glue it. It offers incredible strength for its weight, it's renewable, and we have lots of it!

In this module we will explore aspects of the relationship between our people and our forests. We will learn about the economic and cultural value of our forests, our forest type, and the process of forest harvesting in Newfoundland and Labrador. There is a lot more involved than you may think!

What's So Important About Wood?

In Newfoundland and Labrador, we place strong emphasis on our fishing heritage. But for as long as we have been harvesting fish, we have been harvesting wood as well. More than 80 communities in Newfoundland and Labrador owe their existence to the forest industry.

Our forests hold tremendous economic value. The forest industry generates more than $800 million each year and creates thousands of direct and indirect jobs. Using wood from our forests, companies manufacture many products including lumber, newsprint, moldings, furniture, flooring, and cupboards.

While our forests have strong economic value they also have tremendous cultural value. Archaeological evidence has verified the importance of the forest to the Maritime Archaic, Paleo-Eskimo and Beothuck Indians, as well as today's First Nations people. Countless generations of Newfoundlanders and Labradorians still "head out to the cabin" in the woods to hunt, fish, bird watch, pick berries, and enjoy nature.

Our forests are also home to many species of plants and animals, creating an important bond between our forest ecosystem and these species. Without proper care of our forests, many of these plant and animal species would not exist, and our cultural and natural landscape would be altered.

The Largest Ecosystem on Earth

Our forests are part of the boreal forest ecosystem. The boreal forest makes up about one-third of this planet's total forest area. Running through Canada, Russia, and Scandinavia, it has been called the largest ecosystem on Earth.

In North America, the boreal forest extends from Alaska to Newfoundland and Labrador. It borders the tundra to the north and touches the Great Lakes to the south.

The most common tree type in the boreal forest is the conifer; cone bearing evergreen trees with needle-shaped leaves. Conifers are well-adapted to the harsh climate and thin, acidic soils that are found in this ecosystem.

Large numbers of bodies of water are also characteristic of the boreal forest. Bogs, fens, marshes, shallow lakes, rivers and wetlands are mixed in among the forest landscape and hold large volumes of water. Winters are often long and severe, while summers are short and often warm.

Forests of Newfoundland and Labrador

The boreal forests of Newfoundland and Labrador are relatively small and consist primarily of black spruce (*Picea mariana*) and balsam fir (*Abies balsamea*) intermixed with other conifers and deciduous trees.

Black spruce is the most abundant tree in Labrador and the second most abundant on the island. This species is common on both wet and dry environments and is very tolerant of our unfavourable soil conditions. Black spruce also grows well on fertile sites, but it is a poor competitor among faster growing trees.

Repeated fires have established black spruce across much of central Newfoundland. The nature of its cones, which pop open when heated, gives this species a competitive edge on burned sites.

Balsam fir forms about two-thirds of the forests on the island and one-third of the forests in Labrador. The forests of the island's west coast commonly consist of pure stands of balsam fir that prefers moist, well-drained soils. This species can attain heights of 20-24 meters at the age of 70-100 years on the best sites.

Deciduous trees are found on the island in areas where there are better quality soils, especially the deep river valleys of the Western Long Range Mountains and the Humber and Red Indian Lake watersheds. White birch (*Betula papyrifera)* and trembling aspen (*Populus tremuloides)* are characteristic species. These trees, commonly called hardwoods, can attain heights of 22 meters at the age of 80 years.

Forest Harvesting in Newfoundland and Labrador

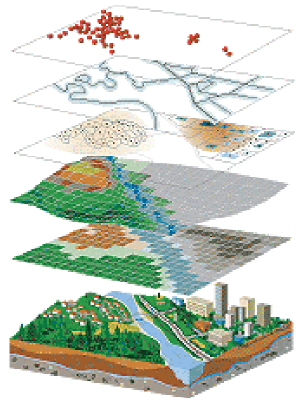
Planning

Forestry harvesting techniques have come a long way since the days of the early loggers, when forest workers put a chain saw over their backs and headed out to harvest the forest's most productive areas.

Today, most of the people who work in the province's forestry sector are highly educated, skilled, and trained individuals. Forest harvesting techniques are now technologically advanced, with a commitment to protect and sustain the environment. Planning shows harvesters what areas to cut. Older trees are cut first, giving younger, developing trees an opportunity to grow.

Before logging companies harvest any forest in the province, an ecosystem inventory is completed. The inventory is essential in the planning process for harvesting timber because it provides information on the height, species, age, and productivity of the forest. Information on wildlife habitat and abundance, soils, ground vegetation, and other features are also collected. This information is used with computer models to determine the impacts that harvesting will have on the local ecosystem.

Forests are dynamic ecosystems. Natural forest disturbances such as forest fires, the blow down of trees due to wind, and insect infestation all occur. Through proper planning, foresters can now



harvest areas to "mimic" the look of a naturally occurring event.

Many communities in our province are located within the timber limits of harvesting companies. Protecting essential natural resources such as water sheds and viewscapes for the tourism sector is of huge importance to many residents. Proper planning ensures a buffer zone is left in place to protect water resources against erosion and other factors that may cause negative effects when harvesting. Proper planning also ensures that cut areas are hidden from view in most communities, thus protecting the beauty and features of the surrounding landscape.

Road Access

In many cases, road construction, not cutting, has the potential to have the most severe impact on the forest environment.

To gain access to the forest, hundreds of kilometres of access roads are built every year. These roads must be built in adherence to strict environmental guidelines. Roads are often constructed in areas where they will have the most positive impact for all parties involved. This includes forest operators, recreational users, and local flora (plants), and fauna (animals). For example a road may bypass a sensitive wetland ecosystem instead of going through it.

Roads and ditches are constructed to strict guidelines when it comes to slope. If the roads and associated ditches are too steep, severe erosion may occur.

Harvesting

Loggers no longer venture into the woods with axes and bucksaws. Tree harvesting has become a specialized science. In most areas of the province, large, computerized mechanical harvesters cut trees. Machines called skidders are then used to haul the trees out once they are cut by the harvesters.

One of the main concerns with harvesting is the damage the machines tires caused while traveling to the harvest site and operating in the harvesting area. Thin tires would sink into the soft soil and leave deep ruts that would severely impact the local landscape and take years to return to their natural state.

Many skidders and harvesters are now equipped with wide flotation tires to prevent rutting and damage to the forest floor. Flotation tires look similar to those on an all-terrain vehicle, except the tires are as tall as a fully grown person! Air pressure in these tires is low so that weight is distributed across a wide area, preventing deep ruts from occurring in the soil. This type of tire also ensures seedlings and other growth is not damaged when skidders run over them. Seedlings are not crushed, but spring back up with no permanent damage.

Silviculture is specialized work that also occurs during harvesting. Silviculture workers remove certain types of trees (older or diseased, for example) from a harvest area. This gives the remaining trees in the area more room to breathe, meaning they are able to get more water, sunlight and nutrients from the soil. Replanting trees is also a part of silviculture.

Before harvesting, foresters have to think of what was already living in the forest before they showed up to harvest the wood. A wide assortment of flora (plants) and fauna (animals) flourished in the area long before humans arrived to the harvest the timber. Strict regulations are followed to ensure wildlife is considered when harvesting timber.

Buffer zones are maintained around rivers and streams. This ensures that the critical aquatic habitat is not disturbed during harvesting. The buffer zone prevents erosion and runoff, increased water temperatures, lack of proper camouflage, and loss of breeding areas.

Some forested areas are set aside as "protected areas" because they are home for special or rare wildlife. Forest companies do not harvest in areas classified as protected areas. This ensures that critical plant and animal habitat is protected. An example is the Main River area and the Little Grand Lake reserve. Both are excellent habitat for the Newfoundland marten.

The Two-Centimetre Tall Forest

When you think of the term *clear-cut*, images of vast mowed-down forests often come to mind. Public perception is often that this type of forestry is the result of poor management and destroys both the visual and natural landscape.

But if you look at the science behind "clear cutting," you will see that it is an effective forest management process that actually mimics natural events such as forest fires and insect infestations.

There is a great amount of science involved in selecting what type of trees to cut, where to cut them, and the type of clear cutting to be involved.

There is a misconception that clear cutting is the same as deforestation. This is not the case. Deforestation is the practice of removing the forest with no intention of regenerating the trees on that area. Usually this involves clearing land for urban expansion or agricultural development. This may occur on a very small scale in Newfoundland and Labrador as some communities grow and expand. Clear cutting in Newfoundland and Labrador is a way of both harvesting and regenerating the forest.

A clear-cut may seem like a dead and barren wasteland. Visually it may appear that all the trees in the area have been harvested. But take a walk through this area and examine the ground. There will be many tree seedlings of spruce, fir, pine and other species – a two-centimetre tall forest. Removing the older trees gives these younger seedlings better access to sunlight and water and gives them the ability to grow and expand. A complete forest ecosystem still remains on a smaller scale until succession regenerates a new, thriving forest.

Foresters don't abandon an area after it is harvested. Trained professionals closely monitor the area for many years to keep a close eye on the succession process. They monitor tree growth, new plant and animal species and other traits.

What about the habitat lost as a result of clear cutting? In some cases, animals may be displaced by clear cutting, but planning ensures the clear-cut is of suitable size so displaced animals will not have far to travel to find a new habitat. Clear cutting is done on a much smaller and localized scale than it used to be.

Clear-cuts often attract a whole new array of animal species. These areas tend to be small and open, and attract many sun-loving plants and tree species. As the trees and plants in the clear-cut grow, shrub and alder species more adapted to a shaded forest will slowly replace the sun lovers.

Clear-cut areas basically do not add or increase animal species. They change what species live and thrive in the area, according to their age, and what they need in terms of living habitat. A new clear-cut may not be a particularly good area for a squirrel, chipmunk, or a Newfoundland pine marten, but it does provide excellent habitat for bear, moose, and young rabbits. As a clear-cut ages and grows, it provides varied structure and food sources suitable for different animals' habitat and food needs.

Clear cutting is ugly at first. Few people would rather stand in a clear cut area than in a lush, boreal forest ecosystem surrounded by fir and spruce. But the ugliness of a clear cut passes, usually sooner than expected! In three to four years, succession has filled in the clearings, the area has lost its brown, disturbed appearance, and the hillside is green in the summer and in the fall, awash in colour. In six to 10 years, the young trees are free to grow above the bramble and smaller shrub like trees. In 10 to 14 years, the young stand of 8- to 10-metre tall trees is again a pleasant place to walk through. Finally, in 35 to 40 years, the growing trees are once again a valuable timber crop and animal habitat.

Conclusion

The Province of Newfoundland and Labrador has a rich and vibrant culture and the forests of our province are a part of the cultural fabric. Our cultural identity, although highly shaped by the sea, has also been shaped by the forests that cover our landscape. Can you imagine Newfoundland and Labrador being the same without logging, hunting, camping and fishing in our forests?

The forest industry makes a huge contribution to our economy and our province. But many people still have the misconception that forest harvesting is a "primitive" operation, and environmental impacts are not considered.

In this module we have shown today's foresters are indeed specialized workers and forestry is a technological field. Foresters undergo specialized training in their field and have a sound grasp on environmental issues concerning their profession.

Humans and forests have had close interaction for thousands of years. The importance of this relationship is often left unnoticed. The human relationship with forests has often been seen in a negative light, but with recent advances in technology, the relationship between humans and the forests has never been stronger.

Questions

1. Identify 3 biotic and 3 abiotic factors that are characteristic of the boreal forest.
2. Why does black spruce dominate in previously burned areas?
3. What is the importance of completing an ecosystem inventory?
4. How has today's forest industry advanced technologically?
5. Identify some jobs created as a result of the forest industry in Newfoundland. Can you think of more than 10?
6. What are the advantages and disadvantages of clear cutting a section of forest?
7. Interactions occur between humans and the forest ecosystem; some of these are positive while others are negative. State 2 positive interactions and 2 negative interactions between humans and the forest ecosystem.
8. Construct a food chain of plants and animals found in the boreal forest.
9. In the two-centimetre forest, young seedlings have better access to sunlight and water. Why is this important for the growth and development of the forest?
10. Describe how a clear-cut changes over time.
11. Explain why the term "regeneration harvesting" might be a better term to use than "clear cutting".

Extensions

1. Research an animal that lives in the boreal forest and create a poster or power point presentation.
2. Visit a recent forest fire or clear cut area. Observe what changes have occurred. Bring a camera and re-visit the site at the end of the year. Keep a record of changes.
3. Ask a NL Forest or Wildlife Conservation Officer or someone else involved with the forest industry to visit your class. Ask them to talk about their jobs and the connection they have to the forest.
4. Research how road construction, in logging operations, can have a negative impact on the forest ecosystem.
5. Conduct research on the harvesting practices and equipment used by logging companies today. How do these practices and equipment reduce the environmental impact logging has on an ecosystem?
6. Investigate the different types of protected areas in Newfoundland and Labrador. What are the criteria for becoming a protected area? Are all protected areas managed and protected in the same way?

References

Bethlehem Olive Wood. Available at: www.bethlehemolivewood.net/Spindle.

Boreal Forest Ecoregion. Available at: http://www.sierraclub.org/ecoregions/boreal.asp.

Boreal Forests of the World. Available at: http://www.borealforest.org/world/can_mgmt01.htm#canmgmt03.

Clear Cut Timber Stands. Available at:

http://www.ces.ncsu.edu/martin/newsletters/newsarticles/twigs/clearcut.html.

Corner Brook Pulp and Paper Sustainable Forest Management Plan. Available at:

http://www.cbppl.com/SFM/locked/SFM%20Plan%20v2.pdfhttp:/www.cbppl.com/SFM/locked/SFM%20Plan%20v2.pdf.

Forest Management Systems. Available at:

http://www.inhs.uiuc.edu/dnr/fur/habitats/forest.html.

Manitoba Model Forest (1996) *Manual for Environmentally Responsible Forestry Operations in Ontario.*

Myth's of Clearcutting. Available at:

http://pfa.cas.psu.edu/news_clearcutting.htm.

Natural Resources Defence Council. Available at:

http://www.nrdc.org/land/forests/boreal/images/page5.jpg.

Newfoundland and Labrador Department of Forest Resources. Available at:

http://www.nr.gov.nl.ca/forestry.

Silviculture in Ontario. Available at:

http://ontariosforests.mnr.gov.on.ca/silvicultureoverview.cfm?lang=FR&lang=EN

Status and Trends in Forest Management. Available at:

http://www.fao.org/docrep/W4345E/w4345e04.htm.

The Canadian Forestry Association (2003) *Canada's Forests-Source of Life: Volume 4, Sustainable Forests.* The Canadian Forestry Association

The Clear Cutting Controversy-Myths and Facts: Available at:

http://www.wvu.edu/~agexten/forestry/clrcut.htm.

The State of Canada's Forests. Available at:

http://www.nrcan-rncan.gc.ca/cfs-scf/national/what-quoi/sof/sof04/special04_e.html.

Transport Models. Available at:

http://www.transportmodels.co.uk/

Tree Regeneration. Available at:

http://www.dof.virginia.gov/mgt/tree-regeneration.shtml

Heat Pumps: An Alternative Way to Heat Homes

Outcomes:

1. Identify different approaches taken to solve the problem of heating homes during cold times of the year (109-7)
2. Make informed decision about the various technologies used to heat our homes, taking into account potential advantages and disadvantages (110-7, 113-8)
3. Provide examples of how the technologies used to heat homes have improved over time (110-8)
4. Provide examples of how our understanding of evaporation and condensation of liquids resulted in the development of heat pumps (111-1)
5. Describe how various surfaces absorb radiant heat (308-6)

Introduction

Heating homes in Newfoundland and Labrador has long been a major concern. Historically, there have been three main sources of heat in this province: (1) wood, (2) oil, and (3) electricity. It takes a great deal of effort to stay comfortable during our cold, damp winters. The effort made may be in labour (e.g., cutting, splitting, and storing wood) or in dollars (e.g., increasing costs of oil or electricity). When building a new house, the choices of the type of heat source for that house has become a very important decision. To make this decision, there are many questions that should be considered about the traditional sources of heat. Some of these are:

Wood:

1. If I cut it myself, will there be places available in the future where I can cut it?
2. If I buy my wood, how expensive will it become?
3. Is there a long term supply of wood in my community?
4. Do I have the time needed to cut it up, store it to dry, and then put it in a shed?
5. Am I aware of the pollution created by burning wood?

Oil:

1. How expensive will it become in the future?
2. Will there be an ample supply in the future?
3. Do I have enough space in my house for the furnace and duct work?
4. Am I able to deal with a spill from the tank or fuel lines?
5. Am I comfortable with the green house gases that are produced?

Electricity:

1. How expensive will it become in the future?
2. What environmental damage results from its production?
3. Will there be enough in the future?
4. Is the source of the electricity environmentally friendly?

The decision of which heat source to install in a new house is not only a costly one, it is a decision that is often not easy to change in the future. For example, changing from oil to electricity (or vice versa) is very costly and, in some cases, is not possible due to how the house was constructed. As a result, the answers to these questions have long term implications for the house owner.

With recent scientific advancements, there are other options to the three “traditional” choices. One of these is the heat pump and is now becoming a very real and practical alternative. A heat pump is an electrical device that moves heat from one source, “concentrates” it, and transfers it to another location. This technology is very similar to that which is found in refrigerators and air-conditioners. In these devices, heat is removed from the fridge or room and transferred somewhere else. As you will see below, this type of heat pump works in the cooling mode only.

The Science Behind Heat Pumps

The heat pump is based on the following two scientific principles:

1. When a liquid is heated it will evaporate (becomes a gas) and when a gas condenses (becomes a liquid), it gives off heat. As you have learned, this is explained using the particle theory of matter. As the particles in the liquid are heated, they have more kinetic energy and are able to move further apart. When particles gain enough kinetic energy, those at the surface can “break free” of the surrounding liquid particles and leave the liquid as a gas.
2. Changes in pressure can make a liquid evaporate, or gases condense, more easily. In other words, if the pressure on a liquid is reduced, the liquid will evaporate more easily. If a gas is put under more pressure, it will condense more easily. A common example of this is a propane tank or propane torch. Propane is placed in a tank under a pressure that causes it to be a liquid (if you shake the tank, you can hear or feel the liquid sloshing around inside). When you release the pressure on this liquid, such as when you open the tap or valve, the liquid evaporates and comes out as a gas. This happens because it is under high pressure inside the tank because the gas is “jammed” into a small space. When you open the valve, the pressure is much less because the gas is entering a much larger space.

These scientific principles are used to make a heat pump in the following way:

1. In the place where heat is to be removed, a liquid, called the refrigerant, is pumped through tubing under low pressure. The refrigerant is a liquid that has a very low boiling point (e.g., where water has a boiling point of 100°C, the refrigerant might have a boiling point of 10°C or lower).
2. As the refrigerant passes through the pipes, it absorbs heat energy from the surrounding environment and, because it has a very low boiling point, it evaporates (becomes a gas). At this point, the gas is under low pressure.
3. This low pressure gas is then pumped and compressed (put under high pressure) into a second area where it releases the heat energy it absorbed. The heat energy that is released can then be used to heat air or water. The warm air or water is then transferred to the location that is to be heated (e.g., a room in a house).
4. The compressed refrigerant is then passed through an expansion valve that reduces its pressure. At this point the gas reverts back into a liquid refrigerant and the process repeats itself.

To cool an area, the process is reversed. Because it is fully reversible, a large heat pump is capable of heating or cooling our homes, offices and schools, depending on the outside temperature.

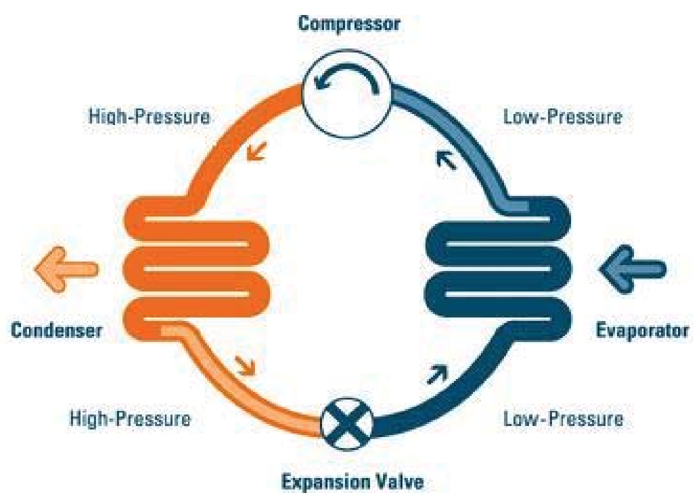


Figure 1: The basic heat pump cycle (photo courtesy of www.nrcan.gc.ca)

You might wonder how this works during the cold winter months. You might ask "where is the source of heat when it's -18°C outside?" As you have learned in this unit, all matter contains energy until it reaches absolute zero (-273°C). So, even at -18°C, both the ground and the air are sources of heat. Furthermore, once you go below the deepest penetration of frost, the ground is at a comfortable 16°C (and will get even warmer as you go deeper). So, even on the coldest days, the air always contains heat. In fact, while it might not feel like it as you stand there shivering, air at -18°C contains about 85% of the heat it contained at 21°C!

Types of Heat Pumps

1. <u>Air-Source Heat Pumps</u>

This type of heat pump uses the energy that is present in the air as a source of heat. Air-source heat pumps are most efficient when the outside air temperature is above -9°C. Below this temperature, the commonly used refrigerants can not absorb enough energy from the air efficiently.

There are two types of air-source heat pumps:

(a) Air-to-Air

This type of heat pump removes heat from the air. If it is being used to heat a house, the heat is absorbed from the air outside then transferred to the air inside the house (see Figure 2). The fan, which is part of the heat collection mechanism (outside the house), pulls air across the pipes that contain the low pressure refrigerant. The refrigerant absorbs heat from the outside air and evaporates into a gas. This gas is then passed through the compressor and pumped inside the house and through a series of pipes and heats the surrounding structure. Inside the house, another fan, which is part of the distribution mechanism, pulls cool air from other parts of the house and forces it across the heated tubes that contain the high-pressure refrigerant. As the air passes over these tubes, it warms up. The fan continues to blow this warmed air into ductwork that carries it to the cooler parts of the house. This warm air heats the interior of the house.

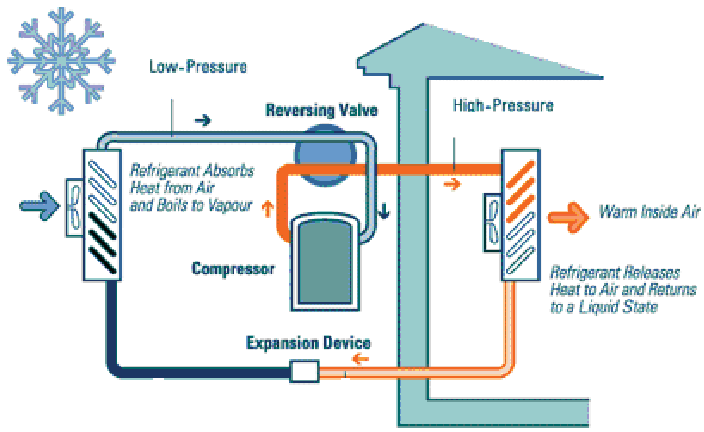


Figure 2: Heat pump in its Heating Cycle (photo courtesy of www.nrcan.gc.ca)

To cool the house, the process is reversed and the refrigerant is pumped in the opposite direction (Figure 3). The fan pulls warm from inside the house, over the pipes that contain refrigerant under low pressure. The refrigerant absorbs the heat from this "inside air" and the heated refrigerant changes into a gas. As the "inside air" looses heat energy, it is cooled. The fan blows this cooler air into the ductwork and throughout the house. The cooler air cools the interior of the house. This gas passes through the compressor and enters the pipes outside the house. Here the fan blows outside air over the surface of the pipes and the outside air absorbs heat energy from the refrigerant. The gas condenses back into a liquid and is under low pressure. It is pumped back into the house and the cycle continues.

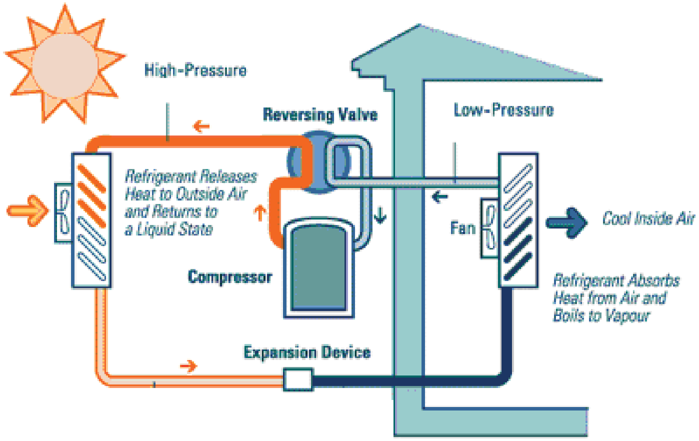


Figure 3: Heat pump in its Cooling Cycle (photo courtesy of www.nrcan.gc.ca)

Notice the differences in the two cycles as displayed in Figures 2 and 3. These are:

i) the "heat in" mode is the reverse of the "heat out" mode
ii) the refrigerant is pumped in opposite directions. During the heating mode, it goes inside the building, while in the cooling mode, it goes outside the building.

(b) Air-to-water

This type of heat pump functions in exactly the same manner as the air-to-air heat pump with the exception that the energy transfer occurs between the air on the outside and water on the inside. For example, during the winter months, the heat pump removes heat from the outside air and transfers it to the water in pipes that are usually placed throughout the sub-floor (under the carpet, canvas or hardwood). This makes the floor warm which in turn heats the home. Or the water may run through a large metal structure called the radiator. The water inside the radiator heats the metal and the heat "radiates" into the room, heating the surrounding air.

2. <u>Ground Source Heat Pumps</u>

The ground-source heat pump takes heat energy from the ground outside the house, when in the heating mode, or deposits heat into the ground outside the house, when it is in the cooling mode.

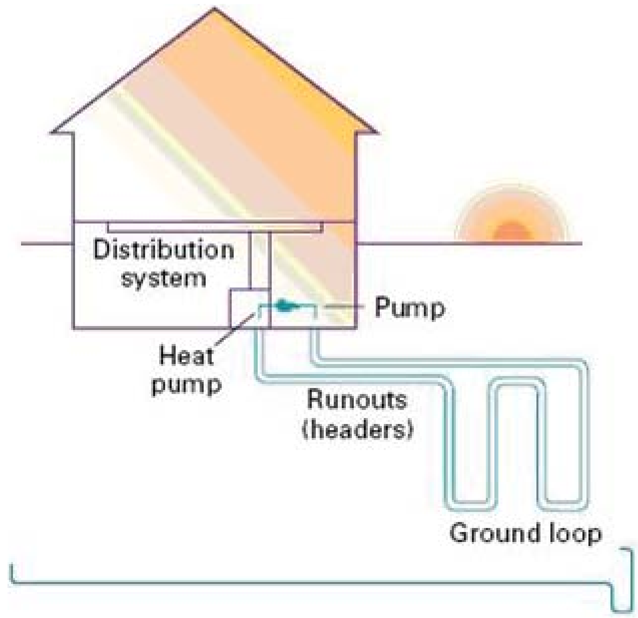


Figure 4: Ground source heat pump (photo courtesy of www.swansea.gov.uk)

The refrigerant is pumped through an underground piping system and picks up heat in the heating cycle or gives up heat in the cooling cycle. The length and depth of the underground piping system depends on a number of factors. These are:

i) the size of the space to be cooled or heated
ii) the difference between the temperature inside the building and the outside temperature
iii) how well the space is insulated

Cost Comparisons

If the home builder is considering the installation of a heat pump as the heat source for the house, there are other questions that need to be considered. Three of the most important ones are: "Which type, air source or ground source is best for me?", "How much will it cost to install a heat pump?" and "Will it save me money on my heating bill?"

The answer to the first question will depend on the general climate in the area. Air source heat pumps are most efficient (i.e., most cost effective) within an average temperature range (which depends on the pump), and if the average temperature in that area falls outside this range, the only real option is the ground source pump. It is difficult to answer the second question as there are many factors that influence the overall cost. Some of the factors that will influence the overall installation cost of a heat pump are: the size of the house, the configuration (i.e., bungalow, 2-storey, etc.), where the house will be located (i.e., the more distant from the supplier, the more it will cost), the temperature range of the outside air, the type of soil that will need to be dug up, etc.

Often, it is the answer to the last question that most people will use to make their final decision. Figure 5 below provides a comparison of the costs involved to heat a 3000 sq. foot house, in a good location and an average temperature range (i.e., -15^{o}C to 25^{o}C).

Analysis

Careful comparison of the various heat sources available will point out pros and cons of each choice. The traditional sources for heating houses in Newfoundland and Labrador (Wood, Oil, and Electric) are cheaper to install but over the long term are more costly to operate. Also, in addition to the negative effects these traditional heat sources have on the environment, the operating costs for these may increase quickly as the supply is reduced. The alternative to the traditional heat sources is the heat pump. There are several positive features related to using heat pumps to heat our homes. These are:

i) they do not have any negative effects on the environment
ii) after they have been installed, they are cheaper to operate than the traditional sources of heat
iii) the operating costs will not change as they are not affected by limited supply or price increases.

Heat Source	Installation Cost	Average cost per month	Yearly cost	Cost in 10 years
electric heat	$2500	$300	$3600	$36,000
oil furnace	$5000	$250	$3000	$30,000
wood furnace	$5000	$130	$1560	$15,600
air-source pump	$12,000	$120	$1440	$14,400
ground-source pump	$25,000	$60	$720	$7200

Figure 5: Cost Comparison for Various Heat Sources

So, with the insignificant effects on the environment along with the stable and relatively low operating costs, why don’t more houses have heat pumps installed? The main reason is the up front cost of installation. Even though a heat pump will save the homeowner money in the long run, the decision to add an extra $5000 to $20,000 on the cost of a new house is more than many people are able to afford or are willing to spend.

Conclusion

While there are many decisions that go into the planning and building of a house, the decision of which heat source to use is one that will have long term effects. This is a decision that is not made easily and each individual home builder has to carefully weigh the pros and cons of each option to ensure he or she makes the best decision to fit their lifestyle and budget.

Questions

1. What are the advantages and disadvantages of using a heat pump to heat your home?
2. Explain how a heat pump functions to cool a building rather than heat it.
3. Name three factors that can influence the overall cost of installing a heat pump.
4. What other household appliances use the same technology found in a heat pump?
5. How does an air source heat pump work to heat a home when the temperature of the air outside is -10^{o}C?
6. Describe the similarities and differences between air source and ground source heat pumps?
7. Using the table above, explain how using a ground source heat pump can actually save you money.

Would You Like Salt On That? Improving Winter Driving Conditions with Road Salt

Outcomes:

1. Identify some positive and negative effects and intended and unintended consequences of using salt on highways. (113-1)
2. Describe how our understanding of the properties of solutions has resulted in better road de-icing technologies (111-1)
3. Provide examples of how road de-icing technologies have affected our lives, our communities, and our environment (112-7)
4. Make an informed decision about the use of road salt as our main road de-icing chemical taking into account the environmental, social, and economics advantages and disadvantages (113-9)

Introduction

Our winter months provide us with the opportunity for many enjoyable activities, such as snowmobiling, skiing, skating, and tobogganing. However, winter also brings the great danger of slippery road conditions. Canada uses about 4.9 million tonnes of de-icing materials each year. Of these, 4.75 million tonnes of this is sodium chloride (rock salt), 0.11 million tonnes is calcium chloride, and the rest is made up of potassium chloride and magnesium chloride. At the local level, road crews in Newfoundland and Labrador use around 200,000 tonnes of sodium chloride and 800 tonnes of calcium chloride each winter.

Safe driving in the winter requires good traction between the automobile's tires and the road. Good traction will decrease the amount of skidding and slipping when driving or stopping. Slippery road conditions are created when moisture from fog, rain, or snowfall freeze onto the road. Also, when cars and trucks drive over snow it becomes compacted and bonds to the road making it very hard for plows to remove.

Using Salt to De-Ice Roads

To prevent freezing of moisture and compaction of snow on roads, salt (sodium chloride) is often used because it lowers the freezing point of water. When the addition of one substance to another causes the freezing point to lower, this is referred to as a **freezing point depression**. Freezing point depression is a **colligative property** of solvents. A colligative property is one which depends on the number of particles dissolved in the solute (not the type of particle). For example, as the number of salt particles dissolved in water increases, the water's freezing point decreases to its lowest possible temperature of -9^{o}C. The lowest freezing point of -9^{o}C is reached when the water has become saturated with sodium chloride (i.e., when the water can not dissolve anymore solid salt). Since salt can only lower the freezing point of water to a maximum of -9^{o}C, it will not melt ice or snow if the outside temperature is less than -9^{o}C. For temperatures colder than -9^{o}C, a substitute is used.

Sodium chloride is not the only chemical used for de-icing roads, nor is it necessarily the best at melting ice. Sodium chloride, which has the chemical formula NaCl, dissolves into two types of particles: one sodium (Na) particle and one chloride (Cl) particle per sodium chloride unit that dissolves. A compound that yields more particles when put into water would lower the freezing point of water more than salt. For example, calcium chloride, $CaCl_2$, dissolves into three particles; one of calcium (Ca) and two of chloride (Cl). Because there are more particles dissolved in the water, calcium chloride lowers the freezing point of water more than sodium chloride.

The following table provides a list of some other chemicals that are used to de-ice roads. Note that each chemical has different advantages and disadvantages to its use.

Applying salt at the beginning of a storm prevents the precipitation from freezing and creates an immediate brine (saltwater) solution. As a result, snow build up can be more easily plowed and, depending on road and weather conditions, a new application of salt may be applied.

Name	Lowest Practical Temperature	Advantage	Disadvantage
Sodium Chloride	-9°C	keeps road surfaces dry	damages concrete and vegetation causes metals to rust
Calcium Chloride	-29°C	melts ice faster than salt	attracts moisture, surfaces slippery below -18°C
Magnesium Chloride	-15°C	melts ice faster than salt	attracts moisture
Potassium Acetate	-9°C	biodegradable	corrosive
Ammonium Sulfate	-7°C	fertilizer	damages concrete

Figure 1: Some chemicals used to melt ice.

* Further research into these chemicals will give a more detailed account of their negative affects on the environment.

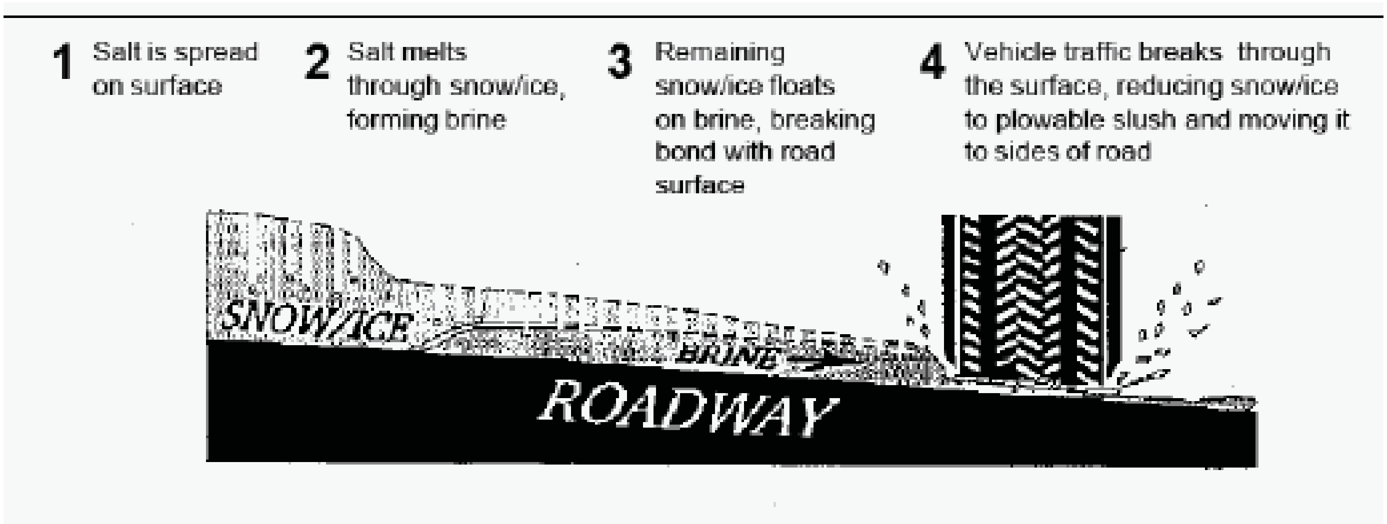


Figure 2: How Salt aids in Ice Removal (Source: http://www.highways.gov.sk.ca/technical-backgrounder/)

Problems with using Salt to De-Ice Roads

Although road salt is very important to help keep our roads and highways safe during the winter months, using too much can have a negative impact on our environment and structures. Some of the problems associated with using salt for de-icing roads are described below.

1. Surface and Groundwater

When salt is spread on the ground it will dissolve in the water that is present in the soil. As a result the groundwater will become salty and this saltwater may then end up in streams, ponds and even in our drinking water supplies. When salt water gets into freshwater ecosystems, it will affect the aquatic life in a negative way and may even kill off some of the living organisms. If communities use the aquatic ecosystem as a source of drinking water, it will affect the quality of our drinking water and may cause it to become dangerous for humans to drink.

2. Impacts on Soil

The sodium part of salt can react with minerals in soil which causes it to become harder. In some cases, the soil is so hard packed that water will not percolate through it easily. Also, because the soil is so hard, it is difficult for plant roots to push their way into the soil. Since plants use some of the minerals in soil for nutrients, this will decrease the soil's fertility and its ability of plants to grow there.

3. Vegetation

High concentrations of salt in soil, groundwater and salt spray from vehicles can damage the trees, grasses and shrubs present along the roadside. As a result, some plants will die off and other, **salt tolerant** plants may move into the area. You may notice that the vegetation along newly constructed roads is different than that along older roads. The vegetation along the side of older roads may have been damaged by salt or may be better able to withstand the salt concentration.

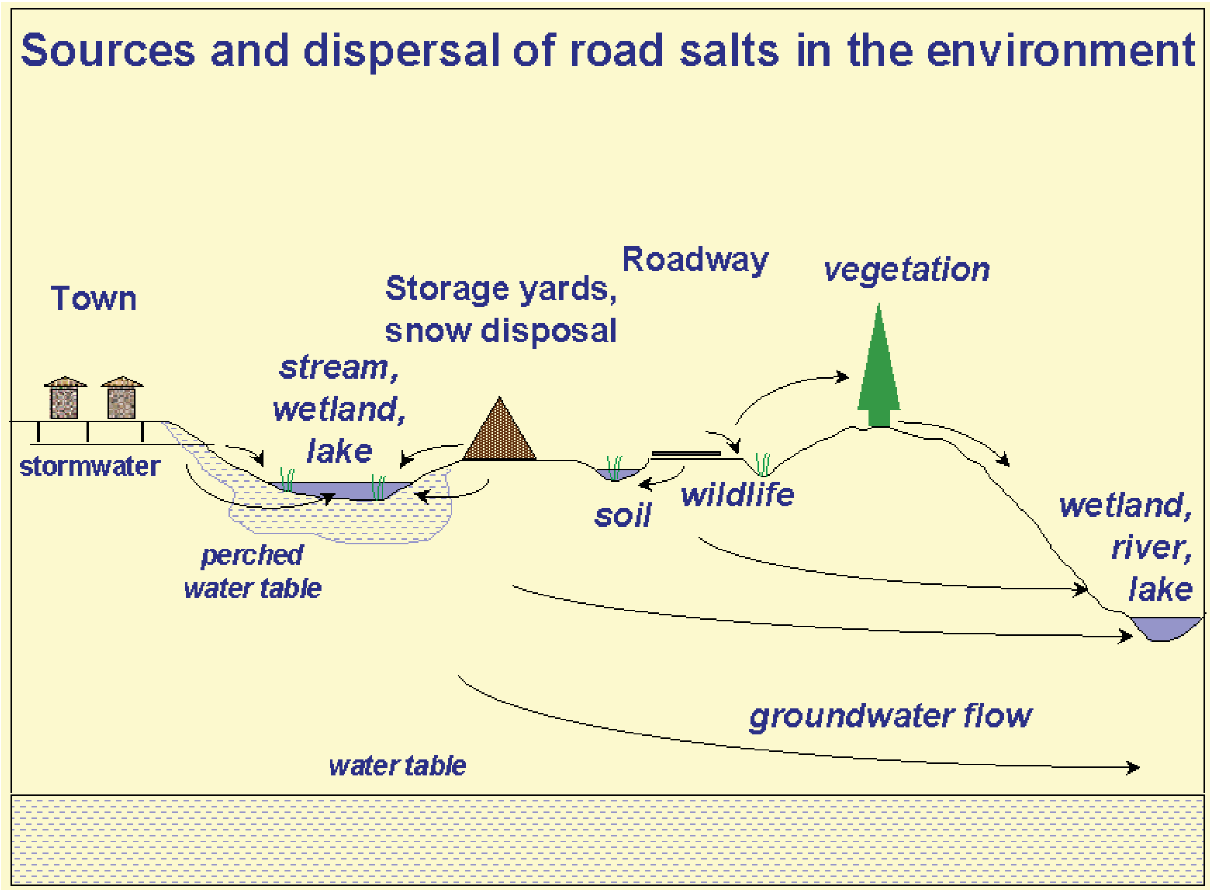


Figure 3: Sources and Dispersal of Road Salts in the Environment

(Source: http://www.ec.gc.ca/EnviroZine/english/issues/14/email_story_e.cfm?page=feature1)

4. Wildlife

Animals, like humans, need a certain amount of salt in their diet to keep them healthy. During the winter plants, which are animals' main source of salt, are not easily available. As a result, animals become "starved" for salt. The roadside provides a readily available and easily accessible source of salt. The salt is not a danger to the animals. However, having animals on or near the roads increases the chance of an animal-vehicle collision.

5. Corrosion of Vehicles and other Structures

Have you ever had the chance to compare the condition of an older car from Labrador with one from the island portion of the province? Road salt (and sea salt) dramatically speeds up the process of rusting. Salt also causes damage to our concrete bridges. Scientists are working to producing better rust resistant paints for vehicles as well as developing salt-resistant concrete.

Reducing the Negative Effects of Salt

In addition to trying to develop paints that slow down the rusting process and salt-resistant concrete, there are several other things that can be done to reduce the negative effects of salt.

1. Anti-icing

To further improve the safety of the roads and reduce the amount of salt used hi-tech Road Weather Information Systems (RWIS) have been set up across our province. These are automatic weather stations that are located near the highway and have sensors on the surface of and under the pavement. The system records the atmospheric conditions, such as relative humidity, wind speed, air temperature, and the temperature and wetness of the road. This information is used by department of highway officials to predict road conditions over a 24 hour period. By using this system, the maintenance crews will know, in advance, if roads will become slippery and will be able to apply salt before this happens. This process, called “anti-icing”, has reduced the amount of salt used by 20 – 30% as well as reducing weather-related accidents by 10 – 15% in some countries.

2. Pre-wetting

Another method used to reduce the amount of salt spread on our roads is to “pre-wet” it. Wetting provides moisture to make a brine, which is then applied to the road, resulting in faster melting action. Also, wet salt has a lower tendency to bounce or be blown off the road by traffic. A savings of 20 to 30% in lost or wasted salt is possible using this method.

Conclusion

Salt has long been the chemical of choice for de-icing our roads. Scientists are continually studying modifications of salt-based de-icing, such as:

i) combining salt with other chemicals
ii) mixing salt with sand in different amounts
iii) pre-wetting the salt before it is applied to the road
iv) ensuring that it is spread on the road in such a way as to maximize its effectiveness and minimize its environmental affects.

While there are some problems associated with using salt to de-ice roads, because of its low cost, abundance and relatively low environmental impact salt is widely used today, and probably will continue to be used into the future.

Questions

1. List and briefly describe the five problems created by using road salt (sodium chloride) on our roads.

2. Explain, with the aid of a diagram, how salt works to create a safer road to drive on.

3. When 10 grams of sodium chloride, NaCl, dissolves in 100 grams of water, the freezing point of the water goes down to -5.9^{o}C. When 10 grams of table sugar, $C_{12}H_{22}O_{11}$, dissolves in 100 grams of water, the freezing point only goes down to -0.56^{o}C. How do you account for this difference?

4. The Department of Transportation use mostly sand on the roads in Labrador. Why? Are the driving conditions in Labrador different from those in places that use salt? Explain your answer.

5. What is the purpose and advantages of Road Weather Information Systems?

6. What are two advantages of pre-wetting the salt before it is put on the road?

Further Research

1. Choose a chemical that may be used instead of sodium chloride as a de-icing chemical. Discuss the cost, advantages and disadvantages of its use.

2. Where are the Road Weather Information Systems located in Newfoundland and Labrador? Discuss how they work and how they are being used by our Department of Transportation.

3. Interview a Department of Transportation worker. Report on the processes of salting, sanding, and clearing our province's roads.

4. Investigate why sugar is used to de-ice aircraft even though it is not as effective as salt in lowering the freezing point of water.

Activity

Design and perform an experiment that tests the effectiveness of different salt concentrations on the: i) the melting time of ice, and, ii) the freezing point depression off the water (this can be studied by adding different amounts of salt to ice and record the lowest temperature reached by the water produced).

Reference Material

http://www.ec.gc.ca/media/index.htm

http://www.ec.gc.ca/substances/ese/eng/psap/final/roadsalts.cfm

http://www.usroads.com/

http://chemistry.about.com/cs/howthingswork/a/aa120703a.htm

http://www.highways.gov.sk.ca/technical-backgrounder/

http://en.wikipedia.org/wiki/Sodium_chloride

http://www.saltinstitute.org/

Seeing The Big Picture

Outcomes:

1. Describe how our explanations of how Earth has changed overtime are based on the collection of evidence and finding relationships between various observations in imaginative ways. (109-2)
2. Describe how our understanding of the forces that shaped our Earth have changed overtime as new evidence was collected. (110-5)
3. Identify the theory of continental drift as one early explanation for how our Earth changed over time. (110-1)
4. Identify the theory of plate tectonics as an example of a major shift in our world view. (110-3)

Introduction

The evidence of the earliest group of humans on our planet dates back 200 000 years. These people were located in the vicinity of Omo Kibish, Ethiopia in eastern Africa. Forty thousand years ago, or 160 000 years later, modern humans spread out of Africa to inhabit the rest of the Earth. It wasn't until relatively recently, less than 600 years ago, that Europeans set sail and explored the continents of North and South America. Over this span of human history the way in which we have pictured our planet has changed significantly.

Figure 1: World view prior to the Columbus 1492 voyage. In Germanus, 1482

(Source: http://www.newberry.org/K12maps/module_01/k-2.html)

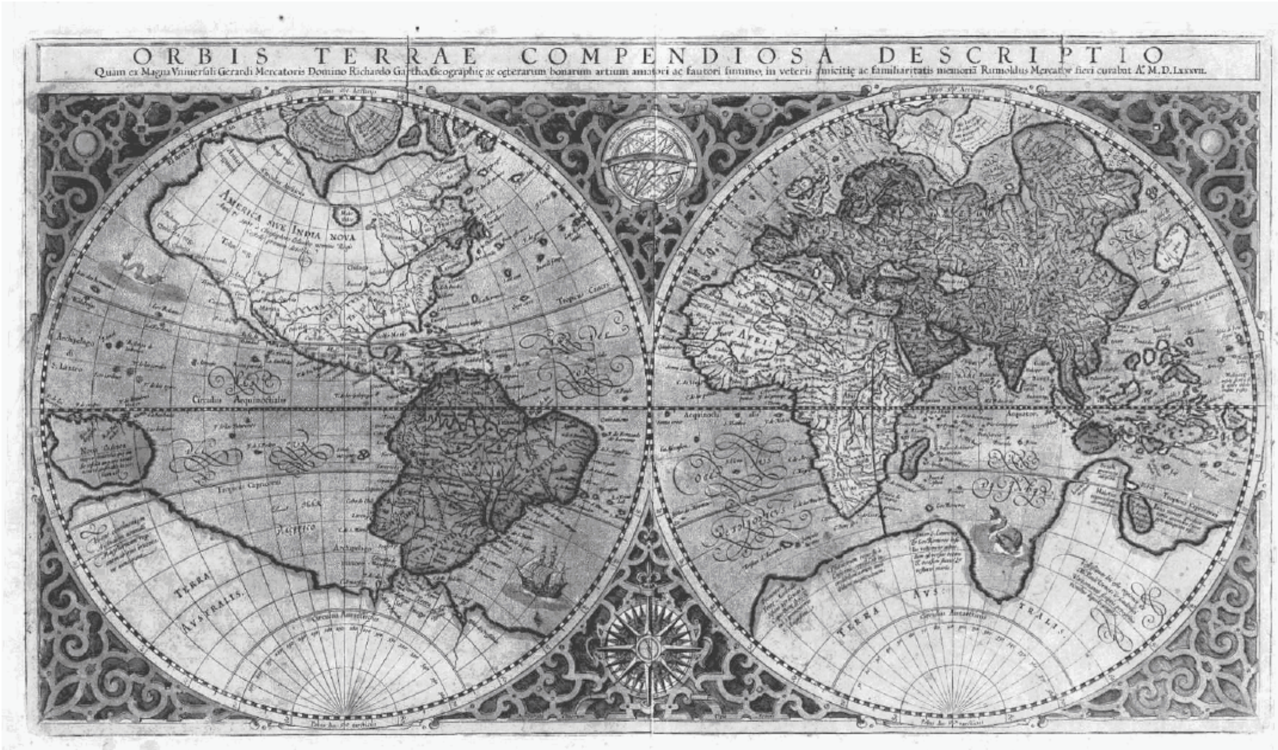


Figure 2: World view after the discovery of the Americas. Mercator, 1587
(Source: http://www.libs.uga.edu/darchive/hargrett/maps/1587m4.jpg)

With European exploration of the Americas the picture of the world changed and so did the thinking of its people. Those who thought of the Earth as being flat were now forced to rethink their old ideas. Early explorers produced maps and from these maps a new picture of our planet emerged.

The Emergence of a New Theory

Try to imagine yourself traveling back, over one hundred years in time, to northern Europe.

You are a teenager who enjoys skating and hiking. You finish school and choose to study meteorology, the science of weather. When you are in your mid twenties you are invited on an expedition to explore Greenland during which time you have an opportunity to observe maps of the Atlantic Ocean. You notice that the shorelines on the eastern part of North and South America seem to match up with Western Europe and Africa. You wonder why this is and question if there is some way in which these two far away continents could have once been joined together as one.

You search for other evidence to support your idea. Remember, the World Wide Web is not available yet so your only alternative for research is to look in books! During your research you discover that fossils of similar species of plants and animals, that are incapable of significant movement, have been discovered on both sides of the Atlantic Ocean. You notice that some fossils of creatures that once lived in the ocean are being found in sedimentary rocks on mountain tops and that minerals that only form in warm climates were being found in polar regions. All of this evidence supports the idea that land masses on our planet have shifted over time. However, one question remains unanswered: What is making them move?

Later in life you are selected to fight for your country in World War I and although you are wounded twice you survive to write down your ideas and publish a book so that others can read about your theory. Most of your friends, including educated members of your own family, still think that your ideas are incorrect. At the age of fifty you have an opportunity to return to Greenland on another expedition and tragically you are lost in a blizzard.

Your imagination has placed you in the shoes of the man who proposed the theory of continental drift, Alfred Wegener. He proposed this theory in 1912 but up until his untimely death in 1930 it still had not been accepted as true because he could not explain how the continents had moved. The explanation of how the continents moved was not provided until 1960, when a scientist named Harry Hess was exploring the Atlantic Ocean. Using sonar Hess was able to map the ocean floor and identify a mountain chain running the length of the Atlantic Ocean. When they drilled into the crust of this area they discovered that the rock got older as they moved away from the ridge. Magnetometer surveys revealed that magnetic reversals occurred in layers parallel to the ridge. These frozen records in the rock also provided evidence to support sea floor spreading and this proved that the continents had moved from their original position because the continents would have moved as the crust moved. It is now thought that convection currents provide the mechanism that causes the plates to spread apart and create new crust.

Over the years, as new observations were made and new evidence was collected, Wegener's theory of continental drift has been refined into our current theory of plate tectonics. The theory of plate tectonics involves large crustal plates that move over the Earth's mantle. In some areas, such as in the mid-Atlantic, the plates are moving apart. In other areas they are pushing together and sliding past one another. Wegener's ideas, supported by the evidence collected by Harry Hess, J. Tuzo Wilson, and others, have given us a global perspective of why the surface of the Earth is shaped the way it is.

Local Effects of Plate Tectonics

Did you know that where you live now was once next door to a different ocean? Long before the Atlantic Ocean formed there was another ocean called Iapetus already there. The Atlantic Ocean was named after the Greek god Atlas. Since the father of Atlas was Iapetus, this was the name given to that old ocean that existed before the Atlantic. Remains of this ancient ocean can be seen in the Central Zone of Newfoundland (see Figure 1).

It is no accident that this island of Newfoundland is such a wonderful place to find marine fossils! The Western Zone represents the eastern edge of the old North American continent and the Eastern Zone represents the western edge of Africa. Using fossil and mineral evidence, scientists have shown that the western edge of Africa was once attached to the Avalon Peninsula. The Iapetus Ocean lay between what is the present day Central Zone. About 500 million years ago, tectonic forces squeezed the Eastern Zone towards the Western Zone pushing up our present day Appalachian Mountains on the west coast of the island and giving rise to the Central Zone, the remains of volcanic islands.

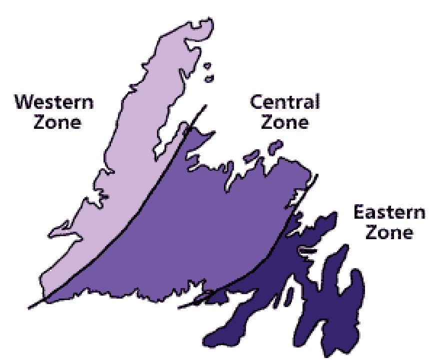


Figure 3: Geological subdivisions of Newfoundland.

(Source: http://www.heritage.nf.ca/environment/nfld_story.html)

The Importance of Plate Tectonics

Scientists have discovered that our continents are moving at a speed of about 3 cm a year. You may wonder why we should be concerned about plate tectonics if the plates are moving so slowly. The small movements that occur in the crustal plates are associated with earthquakes and volcanic activity. For example, on December 26, 2004 an underwater earthquake caused a Tsunami to form which was responsible for the deaths of over 300 000 people in countries around the Indian Ocean. This is equivalent to the number of people who have died due to volcanic activity on our planet since A.D. 1500.

While some plate tectonic forces may be responsible for devastating effects, others may be beneficial. For example, tectonic forces form cracks in the Earth's crust that allow hot fluids from the mantle to seep into the crust and form deposits of precious minerals such as copper and gold. These forces are also responsible for bending the crust and forming shallow seas where salt deposits can form or deeper depressions where oil can be formed. While earthquakes and volcanic activity are relatively sudden events, the processes that form mineral and oil deposits may take millions of years. Many oil and mineral deposits related to these tectonic forces have been discovered in Newfoundland and Labrador.

Plate Tectonics and the Nature of Science

The history of the development of the theory of plate tectonics provides an excellent example of the nature of science. Stop for a minute and consider the following questions: What is a scientist? What do you picture a scientist to be like? What do scientists do on a daily basis? Where do scientists work? What are the characteristics of a scientist?

Does your picture of a scientist portray them as people who wear lab coats as they work in laboratories? Do you think scientists look at the facts that they are presented with and then make an objective decision? Do you think scientists are people who can easily separate their views and opinions from the facts and decisions they have to make? If you said yes to any of these questions then you are not alone. Many people think of scientists as people (mostly male) who work in a laboratory setting, who can put their personal feelings and beliefs aside, and who are not influenced by outside pressures or petty concerns, when they are making decisions related to their work.

Nothing could be further from what happens in reality! Scientists are people just like you, your parents, your teachers, etc., who work in a variety of settings, not just laboratories. And because they are people (both male and female) they make mistakes, they have egos, they ignore evidence that contradicts their viewpoints and beliefs, they are competitive, and they often take their work very personally.

As you have read above, when Wegener first proposed his ideas on how the continents were related to one another, very few scientists believed him. Even when he provided them with very detailed examples from other researchers, his ideas were ignored. You might ask how this could be so… how could the scientists of his day ignore what is plainly obvious to us today? That is a very difficult question to answer. Maybe the senior scientists were jealous of this young upstart. It could have resulted from different interpretation of the data Wegener supplied. It might have had something to do with the fact that it is very difficult to change your opinion about something you have believed in all your life. For whatever reason, many scientists of Wegener's day refused to give any credence to his ideas. In fact, it has been said that, only when the older generation of scientists retire and die off, can a new theory be truly accepted by the scientific community.

Science and scientific activities operate under a set of expectations. To help control personal bias, or even cheating, from affecting scientific decisions, scientists expect that when others provide them with conclusions from experiments, that the data provided is clearly recorded and that the experiments can be repeated to obtain the same data. Science operates from the standpoint that the physical world can be understood through careful, systematic study. Just as in Wegener's time, while scientific ideas are subject to change as new observations are made, normally the new ideas take into account the previous ideas and theories. It is very rare that a scientific theory would be rejected completely. Rather, theories are modified to take into account any new, accepted information. In this way, scientific research is a cumulative process of asking questions, making observations, and, using both the intellect and imagination, trying to make sense out of the observations. If you would like to learn more about the nature of science, refer to the Project 2061 link in the References section.

Conclusion

As humans have evolved on our planet, the way that we frame our thinking has evolved. We are very fortunate that there always seem to be some people that have the ability to see things differently from others. Some individuals pose questions that challenge the things we currently believe. Alfred Wegener was once a young person with an imagination and curiosity about the things that he encountered during his life. These characteristics may have helped him to form his theory. This theory of continental drift evolved into our recent theory of plate tectonics that now shapes the way that we look at the processes that mould our planet. Eventually, knowing where these forces are active may help us to save lives by predicting catastrophic events such as earthquakes and tsunamis. It may also improve our ability to discover new deposits of valuable mineral resources. Many Earth scientists feel that we have just scratched at the surface of the scientific discoveries that will help us understand how our planet, and others throughout the universe, have formed. Most of the mysteries of our planet have yet to be solved. Are you a curious person with an active imagination?

Questions

1. An examination of the map of 1482 reveals significant differences in the way that people viewed the Earth at that time. When compared with the map of 1482, what evidence would Wegener see in the Mercator's map of 1587 that would support his theory of continental drift?

2. What was the missing piece of the puzzle that Wegener needed to support his theory?

3. Does a new discovery always change the way we "see the big picture"? Why/why not?

4. Newfoundland is approximately 4000 km from Africa. If the Earth's crust is moving at a rate of 3 cm per year how long ago would we have been joined together. Do you think that this is possible? Explain your answer.

5. New scientific discoveries seem to spark ideas that lead to other discoveries. The recent technological revolution has created audio and video devices with greater memory capacity in smaller and smaller packages. What technological advances provided evidence to support the theory of plate tectonics?

6. What is a "convection current"? How do convection currents cause crustal plates to move?

7. What are the three pieces of evidence that supports Wegener's theory of continental drift?

References

Alfred Wegener (1880-1930) Available: http://www.ucmp.berkeley.edu/history/wegener.html.

Coleman-Sadd, S and Scott, S.A.(1994). Newfoundland and Labrador: Traveller=s Guide to Geology. Available: http://www.heritage.nf.ca/environment/nfld_story.html.

Project 2061. http://www.project2061.org/publications/sfaa/online/chap1.htm

Ryan, A.B. (1983). Geology of the west coast of Newfoundland. *Newfoundland Journal of Geological Education*, *7*(2). Available:

http://www.nr.gov.nl.ca/mines&en/geosurvey/education/westcoast.stm

Shreeve, J.(2006, March). The greatest journey. *National Geographic*, *209*(3), 60-69.

Map References

http://www.heritage.nf.ca/environment/nfld_story.html

http://www.libs.uga.edu/darchive/hargrett/maps/1587m4.jpg

http://www.newberry.org/K12maps/module_01/k-2.html

Research Ideas

Can you find fossils that link the Avalon Peninsula to Northern Africa?

What geological feature links western Newfoundland to the rest of the old North American continent?

What rock types would you expect to make up most of central Newfoundland?

Activity 1

Purpose: To examine the convection currents that are the driving force behind plate tectonics.

Materials: 1 L beaker and 1 teaspoon of rice in 700 mL of water

Procedure: Students will observe the motion of rice as the water is slowly boiled. Ask them to compare their observations to the motion of magma in the Earth’s mantle. Students should recognize that these hot spots are analogous to plate boundaries.

Figure 4: Convection currents in boiling water

Activity 2

For a simulation of plate tectonic students should explore: http://www.pbs.org/wgbh/aso/tryit/tectonics/

Google Earth can be used explore the boundaries of the crustal plates. Students may be asked to try and find relationships between the plate boundaries and a particular geological feature such as a mountain range, a deep ocean trench, or locations of earthquakes and volcanoes?