Green Teacher

EDUCATION FOR PLANET EARTH

$7.95

Fall 2009 **Issue 86**

Two-Eyed Seeing: Integrative Science

Vitamin C Trees: Traditional Medicine

Linking Astronomy and Legend

Integrative Science with Native Elders

Resanctifying Nature through Story

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Green Teacher is published quarterly in September, December, March and June.
Subscriptions: Canada-CAD $30.48 plus $1.52 GST/$3.96 HST; USA-USD $32; all others CAD/USD $42 air mail
ISSN 1192-1285; GST Registration No. 124125337; Canada Post Publications Mail Agreement No. 40069238; PAP Registration No. 08981
US Postmaster: Send address changes to Green Teacher, PO Box 452, Niagara Falls, NY 14304-0452.
Canada Post: Send address changes to Green Teacher, 95 Robert St., Toronto, ON M5S 2K5. Return postage guaranteed.
Printed in Canada.

Green Teacher

Issue 86, Fall 2009

Green Teacher is a nonprofit organization incorporated in Canada.

Design and Production
Cover illustration by James Paterson; cover design by Michael Kelley; printing by General Printers, Oshawa, Ontario, on acid-free paper certified by the Forest Stewardship Council and the Rainforest Alliance.

This issue is supported by the Natural Sciences and Engineering Research Council of Canada.

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Editorial

On an island in the middle of the St. Lawrence River, at the intersection of Ontario, Québec and New York, sits the Akwesasne Mohawk School. Twenty years ago, the school revamped the Grade 6–8 science curriculum so that their students could more confidently "walk in two worlds" when they left the island to go to public high schools across the river in Ontario. The program stressed the importance of local ecosystem knowledge, and graduating students were expected to recognize 50 local birds, identify the tracks of local mammals, understand the medicinal properties of plants, and be able to map the streams and rivers in their watershed. To facilitate such learning, Native elders accompanied students on numerous field trips during the school year. The new curriculum was so successful that teachers in non-Native schools nearby began asking if their classes could join the field trips. They recognized that the holistic, bioregional view of the environment imparted in Native science provided an essential counterpoint to the objective, analytical view imparted through Western science.

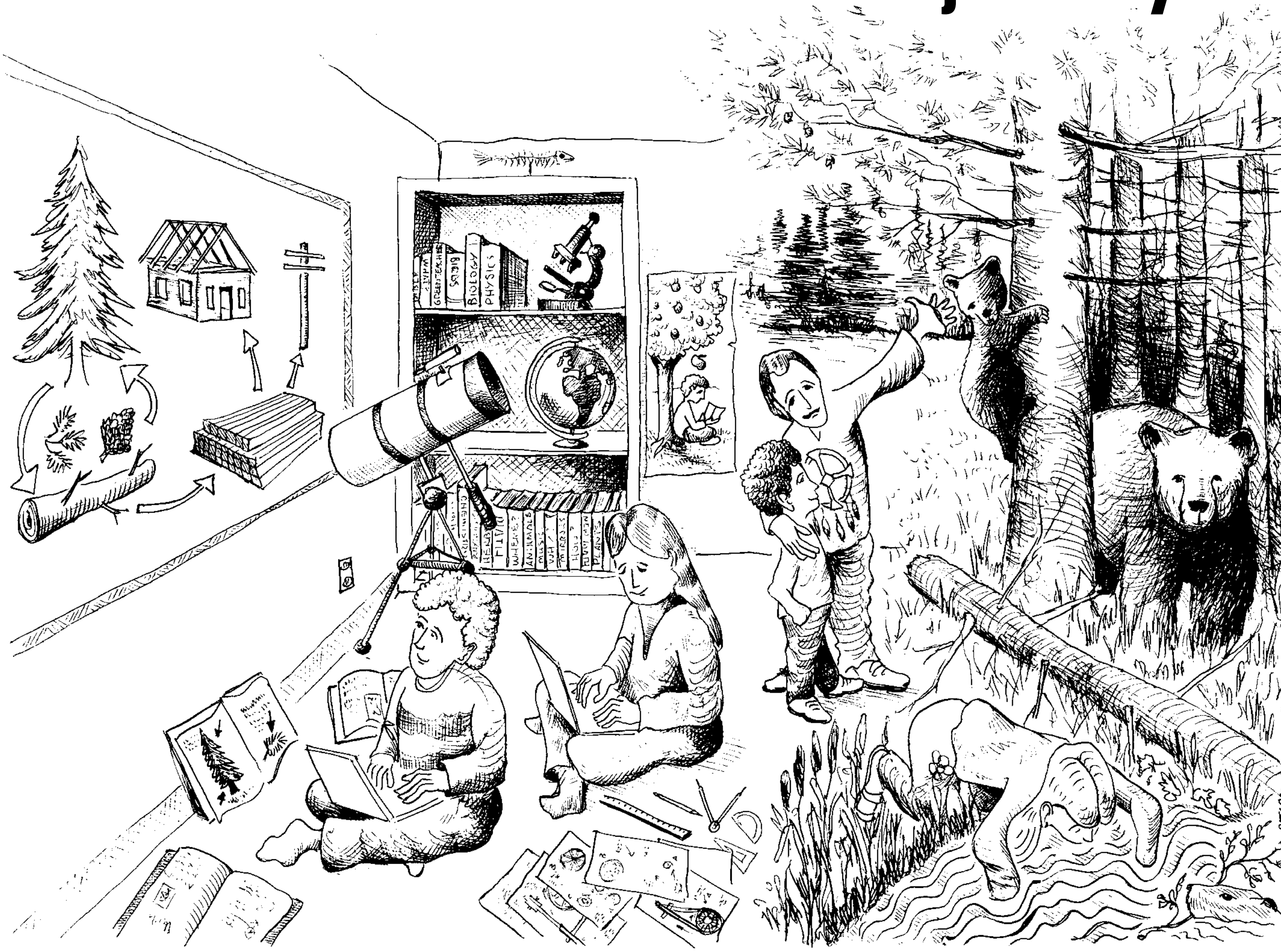
Having published the story of the Akwesasne curriculum project many years ago, we were excited to learn last year about the integrative approach to science education currently being taken by Annamarie Hatcher, Cheryl Bartlett and their colleagues in the Institute for Integrative Science and Health at Cape Breton University in Nova Scotia. Inspired by the concept of "Two-Eyed Seeing" developed by Mi'kmaq Elder Albert Marshall, their science program aims to help students learn "to see from one eye with the strengths of Indigenous ways of knowing, and from the other eye with the strengths of Western ways of knowing, and to use both of these eyes together." In this issue, we present some of the learning activities that they and others have designed for teaching science in this way, thus enabling students to take the best from both world views, Indigenous and Western.

Regardless of where one teaches, integrating the sciences and world views of local Indigenous peoples into the curriculum can be a fascinating inroad to a more bioregional education, one that enables young people to develop a strong sense of place, a respectful relationship with other species, and an awareness of their responsibilities as stewards of the land and resources they and future generations depend on. We hope you will find much in this issue to inspire your own teaching, and, as always, we welcome your comments.

— Tim Grant and Gail Littlejohn, Editors

Note about terminology in this issue:
Native Americans, First Nations, Aboriginal peoples, Indigenous peoples... depending on where you live, you may be more familiar with one of these terms than with the others, but they are synonymous. All refer to the original peoples of a particular region.
In editing this issue, we have chosen not to strive for consistency, but rather to let the individual authors use the terms of their choice.

Two-Eyed Seeing:
A cross-cultural science journey



Illustrations: James Paterson

by **Annamarie Hatcher**, **Cheryl Bartlett**, **Murdena Marshall** and **Albert Marshall**

THE SCIENCE FAMILIAR TO most of us from school is often referred to as "Western" because of its origins in Western Europe. Yet with its objective approach and mechanistic view of the world, Western science can seem like a foreign culture to many students. According to the Canadian Council for Learning, "the acquisition of science knowledge is often symbolic, abstract and counter-intuitive, unlike the acquisition of everyday knowledge, which is usually pragmatic, personal and based on experience."[1] There are many different ways of knowing, and one of the challenges for teachers is building bridges among them with their students. This challenge is being faced in the Integrative Science program at Cape Breton University as a small group of educators, academics and Mi'kmaq elders build bridges between Western sciences and Indigenous[2] sciences. Guided by the Mi'kmaq culture, Integrative Science represents the coming together of Indigenous and Western sciences in a type of co-existence, a functioning of both systems side by side, as recommended by Battiste.[3] This bridge building began as a way to address the serious under-representation of Aboriginal students in scientific fields. However, the approach is beneficial to all students because it adds an engaging cultural dimension to science studies, provides context for learning about other nations, and demonstrates that all knowledge has a cultural context.

In the Mi'kmaq language, *Toqwa'tu'kl Kjijitaqnn* (Integrative Science) means bringing together Indigenous and Western knowledge using the guiding principles of "Two-Eyed Seeing,"that is, to see from one eye with the strengths of Indigenous ways of knowing, and from the other eye with the strengths of Western ways of knowing, and to use both of these eyes together. By concentrating on common ground and respecting differences, we have begun to build a bridge between these two ways of knowing. In this and several companion articles, we present concepts and lessons that lie in the common ground between the two.

Science sub-cultures

It is important to reflect on the evolution of the word "science." Today's scientists embrace fundamental worldviews that are shaped by the origin and evolution of science in the social transformations in Europe in the 1600s. The empirical approach of Western science arose in opposition to the authority of church and monarchy, and its emphasis on quantitative objectivity involves a disconnection between the observer and the observation. With the birth of the British Association for the Advancement of Science in 1831, the word "science" became applied to the Western (i.e., Eurocentric) approach that is commonly practiced today. Before this, "science," derived from the Latin *scientia*, simply meant knowledge.[4]

In verb-based Indigenous languages, knowing is more about the journey than about the destination. Indigenous worldviews do not subscribe to the anthropocentric hierarchy of the Western worldview, but rather to a more natural balance of all creation. Indigenous sciences encompass a large range of "coming to know" processes that result from human experiences in the natural world. Knowledge is gained from the interaction of "body, mind, soul and spirit with all aspects of nature."[5] Battiste and Henderson summarize the structure of Indigenous ways of knowing as follows: 1) knowledge of unseen powers; 2) knowledge of the interconnectedness of all things; 3) a perception of reality based on linguistic structure or ways of communicating; 4) knowledge that personal relationships bond people, communities and ecosystems; 5) knowledge that traditions teach specialized knowledge related to morals and ethics; and 6) knowledge that extended kinship facilitates the passing on of social traditions and practices from one generation to the next.[6]

Indigenous sciences are underlain by the perception of multiple realities, of which the reality perceived by our five senses is but one.[7] Thus Indigenous knowledge is more than the opposite of Western knowledge and should be seen with eyes unbiased by the dominant Eurocentric outlook. This is a formidable challenge for teachers in the current education system. The basic premise of Western sciences is that nature is "knowable,"[8] and thus Western scientists seek to know how the universe works. The Indigenous view of nature comes from deeper within the human psyche than intellectual curiosity.[9] The basic premise of Indigenous sciences is seeking to know what nature is, not how it works.[10]

Why two sciences for students?

Multi-science perspectives about nature expose students to a rich array of knowledge and ways of living, and open up opportunities to link science with other disciplines such as history and English. For example, Integrative Science provides fertile ground for development of multidisciplinary theme-based units for all grades. For all students, and especially those who plan a future in resource management, science or engineering, Integrative Science helps to develop a multifaceted understanding of nature and problem solving and the personal role of the scientist in the conduct of the science.

At the World Conference on Science in 1999, UNESCO and the International Council for Science urged governments to promote understanding of Indigenous knowledge systems. They recommended that "scientific and traditional knowledge" be integrated into interdisciplinary projects with links between culture, environment and development.[11] In this and companion articles we will outline some ways to follow this recommendation with respect to teaching science in schools.

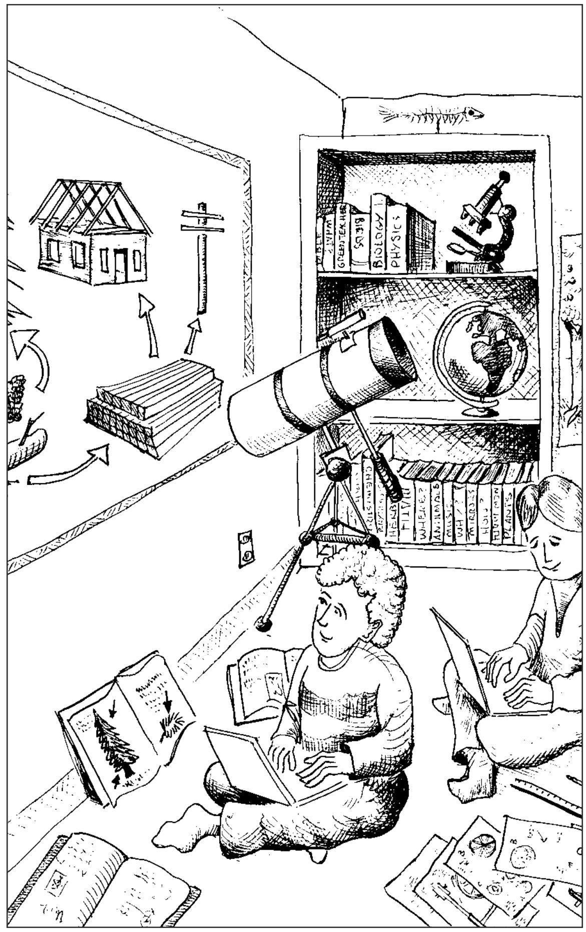
In verb-based Indigenous languages, knowing is more about the journey than about the destination.

Two-Eyed Seeing

It was Mi'kmaq Elder Albert Marshall who brought the concept of Two-Eyed Seeing to Integrative Science. Marshall's experience in residential school led him on a lifelong quest to connect with and understand both the culture he was removed from and the culture he was forced into, and to help these cultures live in mutual respect of each other's strengths and ways. Two-Eyed Seeing recognizes that in a particular set of circumstances we may choose to call upon the strengths of Indigenous sciences, and in another set of circumstances we may choose to call upon those of Western sciences. For example, when we need to compare plant abundance in two habitats and communicate the results to others, we rely heavily on standardized data acquisition, analysis and summarization from Western sciences. But when we wish to teach our children how to catch trout, we teach about the trout, their life cycle and their habitat by experience and by example.

This teaching is holistic, in that the child becomes familiar with cues from several of her senses, drawing on some of the strengths of Indigenous sciences. She will learn the smells of cool freshwater, the sounds of swiftly flowing streams and the visual patterns of insect abundance, and relate these to the movements of the trout. This knowledge is easily passed from those with experience and reinforced by the child's interaction with nature. This interactive aspect of learning is imbedded in Indigenous sciences.

In weaving back and forth between knowledges, Two-Eyed Seeing avoids a clash or "domination and assimilation" of knowledges.[12] As the child grows and learns more Western sciences, she will realize that the smells associated with good catches of brook trout (*Salvelinus fontinalis*) are related to the animals' physiological requirement for highly oxygenated water at temperatures less than 20 degrees Celsius. These environmental conditions provide habitat for diatoms, which have a very identifiable smell. The shallower rapidly-flowing waters where brook trout feed have gravel and rocky bottoms that produce an identifiable sound as water rushes by. The waxing and waning patterns of insect abundance provide clues to the position of the feeding trout and to the type of bait that may be most effective. This can be related to the large body of Western scientific knowledge of preferred prey items of trout, largely catalogued from analyses of gut samples. For Two-Eyed Seeing, we can take the best from our two worlds, Indigenous and Western.



Lying at the juxtaposition of two worldviews, Integrative Science involves a practical engagement with the real world.

Western sciences emphasize objectivity and de-emphasize the subjective human element, yet we depend heavily upon them and their technologies in our modern lives. In the Indigenous worldview, emphasis is placed on the concept of "all my relations." This includes not just our human families, but animals, plants, rocks and other parts of the ecosystem, which are all included in Mother Earth and Father Sky. Components of nature are viewed as spiritual beings, not in order to explain natural phenomena but because human beings experience a spiritual resonance in nature. "Two-Eyed Seeing teaches you to awaken the spirit within you," explains Albert Marshall. "You become a student of life, observant of the natural world. Two-Eyed Seeing teaches that everything is physical and spiritual."

Pattern-based knowledge and the multiple intelligences

Patterns are abstract, culturally-influenced ways of creating order out of apparent disorder through space and time. In the context of Integrative Science, scientific knowledge is considered to be dynamic, pattern-based knowledge shared through stories about our interactions within nature. Different cultures shape and share stories about natural patterns in different ways by using few or many of our multiple human intelligences. The educational theory of multiple intelligences, first developed by Howard Gardner in 1983,[13] describes seven kinds of intelligence: linguistic, logical-mathematical, spatial, bodily-kinesthetic, musical, interpersonal and intrapersonal. In 1998, Gardner added "naturalistic" intelligence.[14] He proposed that individuals manifest varying levels of these different intelligences.

Of the eight intelligences recognized by Gardner, Western sciences tend to draw most on the logical-mathematical (enumerating) and linguistic (reading, writing). For example, scientific names of plants may describe their morphology, but they may also describe a plant's ecology or geography, or honour a person. Wintergreen (or teaberry), a common forest understorey plant of northeastern North America, has the scientific name *Gaultheria procumbens L*. The common name, wintergreen, provides descriptive information about the plant, and "teaberry" describes one of its uses. The genus name, "Gaultheria," honours the J.F. Gaultier, king's physician and naturalist of New France (1708–1756); and "procumbens" means "prostrate or lying down," a reference to the plant's ground-hugging habit. The connection between the plant and the physician Gaultier is the product of a predominantly linguistic intelligence.

Indigenous sciences tend to draw upon the interpersonal, intrapersonal, musical, bodily-kinesthetic, spatial and naturalistic intelligences, as well as the spiritual (considered but not definitively proposed by Gardner). The Mi'kmaq word for the wintergreen plant, *Kaqawejumanaqsi'l*, relies on a naturalistic intelligence that relates the plant to its ecological role in the forest. The word is derived from *Kaqawej*, which means "crow," and *uman + aqsi'l*, which means "berries + plant." Similarly, musical intelligence plays a significant role in naming other creatures in the Mi'kmaq language. *Ti'am*, the Mi'kmaq word for moose, is said to mimic the sound that the animal makes.

> *Two-Eyed Seeing recognizes that in a particular set of circumstances we may choose to call upon the strengths of Indigenous sciences, and in another set of circumstances we may choose to call upon those of Western sciences.*

Integrative Science in the classroom

Whereas Western science education is heavily book-based, often relying on the observations of others, Indigenous sciences represent knowledge that is based on personal experience in the natural world. Within any classroom, there is a wide range of such experience among students, and investigating these multiple relationships is the first of the four key challenges in presenting Integrative Science in the classroom.

Emphasis in the Indigenous sciences is on "change, wholeness and balance," whereas Western sciences focus on parts and emphasize practitioner specialization. The second key challenge in bringing Integrative Science to the classroom is that classroom resources are heavily biased in favour of particular science disciplines. Resources based on more holistic understandings are scarce.

The third key challenge in teaching Integrative Science in the classroom is that today's students are very familiar with computer-mediated entertainment and communication, but tend to have an impoverished personal understanding of nature, regardless of their worldview. The focus on computer resources tends to nurture a pattern of learning that is one-dimensional (i.e., verbal information processing) rather than multi-dimensional (i.e., information processed through all of the senses and integrated).

The fourth key challenge of Integrative Science in the classroom is to guide students to their own spiritual connection with nature, a challenge shared with all environmental educators. Spirituality is a difficult concept to present in a standard classroom.

To meet these four key challenges, teachers can employ the principles of Two-Eyed Seeing, emphasizing Aboriginal concepts such as *MSɫT No'kmaq* (we are all related), and using Aboriginal pedagogical resources, such as the medicine wheel, an ancient symbol used by almost all the Native people of North and South America to teach concepts related to change and balance.[15] Teachers must frame multidisciplinary science within contexts of interest to the students using an inquiry-based learning approach. This includes guided outdoor experiences that reinforce concepts learned in the classroom, learning opportunities in the community, and sessions with elders and other local knowledge holders.

Science is a way of knowing that involves observation, analysis and the construction of a complex understanding of nature. The currently devastating impact of humans on the natural environment is in part a manifestation of the anthropocentric Western worldview and of the objective, non-personal approach to nature that characterizes Western sciences. Lying at the juxtaposition of two worldviews, Integrative Science involves a practical engagement with the real world. More important, it involves a realization of a spiritual resonance in nature that is integral to the Aboriginal world view and may be the key to restoring a healthy relationship with Mother Earth. It is an approach to science that should be familiar to all environmental educators.

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Acknowledgements: Integrative Science developed with the guidance of many Mi'kmaq elders. We thank them for their interest and contributions. In particular, we thank **Jane Meader**, spiritual leader of Membertou First Nation, for her input, and **Sana Kavanagh** and **Rod Beresford** for stimulating discussions and ideas.

Notes

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MSɨT: Transdisciplinary, cross-cultural science

An Integrative Science unit on birds for high school students

Ray Cromie

by **Annamarie Hatcher** and **Cheryl Bartlett**

THE THEME "BIRDS" is a productive avenue for exploring many questions that can be incorporated into presentations, outdoor activities and laboratory exercises. Birds have a cultural significance and a strong presence in many legends of the Mi'kmaq and other Aboriginal peoples, and serve as a link between the present interests of students and the past interests of their ancestors. In observing birds, students observe their surroundings and arrive at a more holistic understanding of their environment. Birds are also of interest to many parents and grandparents, and this encourages students to share stories and information with family and community members.

Here we outline the basics of a question-based approach to the theme "Birds" for high school students. It is adapted from the MSɨT curriculum in the Community Studies in Integrative Science program at Cape Breton University in Nova Scotia. MSɨT is a Mi'kmaq word meaning "everything together," and the MSɨT curriculum employs the "Two-Eyed Seeing" approach of integrating Western and Aboriginal world views. The classroom mirrors the world outside the window, and practical engagement with that world is an integral part of the curriculum. Indigenous science concepts, such as the interrelatedness of all things, are examined in the context of natural cycles at all time and space scales.

The bird-friendly classroom

Students can begin to gain familiarity with birds by installing birdfeeder "watch stations" in nearby natural areas and sheltered spots outside classroom windows. Choose at least two different habitats, such as the north and south sides of the building, or among trees and out in the open. As students log their observations, they should note spatial and temporal patterns in the numbers, types and behaviour of birds. They can generate hypotheses to explain these patterns, as well as compare them to weather patterns that are easily measured with thermometers, rain gauges and hand-held anemometers. For bird monitoring resources, see Project Feeder Watch <www.birds.cornell.edu/pfw/>.

Left: Brete Griffin; Right: Gail Littlejohn

Transdisciplinary understandings

1. Where do birds fit on the evolutionary tree of Western science? How does this relate to the Aboriginal concept that we are all related?

This topic incorporates aspects of the Western disciplines of genetics, evolutionary theory, biochemistry, geology and astronomy, and the Native understanding of the interrelatedness of all things.

Genetics and biochemistry: Genetics concentrates on living things, whereas the "we" in "we are all related" refers to both living and non-living components of an ecosystem. If we extend our view back to life's basic building blocks, we come to a non-living component: the phosphorus atoms in amino acids, which make up DNA. The molecular building blocks of our DNA may have once been incorporated into the DNA of a bird, a dinosaur or a tree. Atomic components were once part of rocks and, even further back, of a star or of space dust.

Evolutionary theory: The skeletons of humans and birds have many homologous (similar) structures, a reminder of the evolutionary connection between them. Students can compare and contrast skeletons of birds and other animals, beginning at The Biology Corner website, where they can colour homologous skeletal structures. Try cutting out the skeleton pieces and have the students re-assemble them and discuss the degree of similarity. See <www.biologycorner.com/worksheets/comparing_avian_human.html>.

Geology and astronomy: Some natural cycles proceed over very long time scales and change the Earth's surface (such as through plate tectonics and continental drift). Others, having to do with changes in the shape of Earth's orbit (eccentricity), the wobble on its axis (precession) and its axial tilt, result in the Earth being closer to or further from the sun at different times. Because of these cycles, Mother Earth experiences periods of glaciation and warming, so that birds may have evolved in a climate very different from the one we now experience. Many birds now migrate long distances, having adapted strategies in their evolutionary past to avoid solid masses of ice. The cycle of precession caused our ancestors to see a different pole star, and our descendants will see yet another. Students can see a simulation of the precession cycle at <http://cse.ssl.berkeley.edu/lessons/indiv/beth/beth_precess.html>.

2. How is flight in birds related to my environment?

This is a good topic for introducing basic principles of physics and the concepts of adaptation and natural selection.

Physics: The shape of a wing causes air pressure to be higher below it than above it. This creates lift, a positive force that allows birds (and airplanes) to fly. If the wing is shaped differently, airspeed over the wing changes and the amount of lift changes.

Natural selection: Function dictates form in the design of bird wings, a match that has resulted from the pressures of natural selection. Short, stumpy wings (with low aspect ratio) are characteristic of birds that live in the forest and fly among tree trunks. They are capable of rapid takeoff and maneuvering but cannot sustain high speed. Similarly, aircraft manufacturers outfit short-hop aircraft that have to be very maneuverable with low aspect-ratio wings. Soaring seabirds, on the other hand, use long narrow high-aspect-ratio wings to take advantage of updrafts created on windward slopes. The eagle (*Kitpu*) carries prayers to the Creator on its wings, and its "finger-tip" feathers help it to maneuver. Wing and feather adaptations can help to introduce concepts of natural selection. Students might calculate aspect ratios of various birds' wings, matching these with habitat or flight characteristics.

3. What can birds tell us about weather?

Birds are very good weather predictors. In our region of Cape Breton, the local abundance of some short-distance migrators such as the common Redpoll and the White-winged crossbill is a reflection of the food abundance in their habitats farther north. The appearance of large flocks of redpolls in early winter is often a harbinger of a hard winter; in mild winters, they stay in their more northerly habitats. Seagulls often appear in sheltered inland waterways when a marine storm is approaching. (*"When the seagulls fly to land, there is a storm at hand."*) For students living near

Annamarie Hatcher

large water bodies, this can form the basis of a simple exercise of monitoring seagull numbers in certain sheltered sites and correlating the numbers to offshore wind speed.

4. What role do birds play in science and legend?
Birds have a significant presence in Mi'kmaq science because their abundance and distribution are indicators of weather patterns, productivity of various plants, environmental disturbances and of other, related phenomena, such as fish abundance.

Birds also play a significant role in many Aboriginal legends, such as the Mi'kmaq story of "The Bird Whose Wings Made the Wind." In this legend, a large bird called The Storm King causes winds to be so intense that the families on the seashore cannot spear eels. One man tricks the bird into letting him carry him to shore. But the man drops the bird, and his wing is broken. The man binds both wings and brings food to the bird. Because the wings of the bird are bound, the winds cease and the weather becomes calm, allowing the villagers to catch many fish. This seems ideal, but it is too much of a good thing, and a dense scum forms on the ocean because of the lack of water circulation. The scum prohibits eel spearing because the hunters cannot see into the water. The man visits the bird again and frees one of its wings. With the winds now gentle and steady, the water begins to circulate properly and the villagers are able to spear enough eels to feed their families.

The connection between our stories and our treatment of the natural world is one that Western storytellers and educators have perhaps failed to realize.

This legend conveys a strong message about ecological relationships and the unpredictable consequences of interfering with natural processes. In the oral traditions of Aboriginal people, such legends served to educate and amuse. Students may generate their own stories by reading articles on environmental issues and then writing simple stories to convey environmental messages. The "Native Drums" website has good sections on myths and stories See <http://nativedrums.ca/>.

5. What can birds tell us about the health of our environment?
For the Mi'kmaq people, the bald eagle (*Kitpu*) is the messenger to the Creator because it flies high and is respected by all creatures. Kitpu and other birds are also sensitive environmental indicators, as evidenced during the DDT crisis of the mid-20th century. Seabirds follow schools of fish, and many cultures have used them as indicators of fish accumulations. A modern example of birds as environmental indicators is the devastating impact of pesticides in South and Central America on songbirds that migrate back to North America.

Integrative Science is underlain by pattern recognition and an intimate, respectful relationship between the scientist, the natural world and different worldviews. Following the question-based approach outlined above, there should be a natural progression, from observation of spatial and temporal patterns of bird abundance outside of a bird-friendly classroom, to discussions of natural selection and evolution, to the physics of flight, to the dynamic nature of our local environments over long temporal scales due to extra-planetary forces. The Western science meshes elegantly with an exercise on story-telling and the oral tradition, which could lead the class in several directions. With their teacher using birds as a catalyst to make them look at what is outside the school doors, students will leave this theme with a renewed appreciation of their local environment.

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Traditional Medicines: How much is enough?

An integrative science activity for senior elementary and junior high students

Photographs: Shara Johnson

by **Annamarie Hatcher** and **Cheryl Bartlett**

BEFORE THE DAYS of pharmacies and vitamin pills, Aboriginal people harvested plants for medicine and used tonics that contained significant quantities of vitamins and minerals. This exercise is an investigation into early methods of measuring dosages of medicinal tonics. It could form the basis of math and chemistry exercises and provide an opportunity to incorporate lessons on nutrition. The topic is well suited to students in upper elementary or junior high school.

Background

In many Aboriginal cultures, teas were both refreshing drinks and medicinal tonics. For example, teas made by steeping the needles from various conifers in boiling water are very high in vitamin C and served as a significant source of this nutrient, particularly in winter. It was tea made from eastern white cedar by Mi'kmaq people that cured Jacques Cartier's crew of scurvy in the winter of 1535–1536.[1] As well as being astringents, conifer needles have antiseptic and stimulant properties due to the monoterpenes in their resins and essential oils. However, conifer needles contain other compounds that are toxic if consumed in large quantities. These are secondary metabolites, such as tannins, produced by plants to discourage herbivores. Because of these secondary metabolites, it is very important to limit consumption of medicinal teas to doses that are appropriate to body size.

Infusions of the needles of tamarack (*Larex laricina*) or red spruce (*Picea rubens*) were used by many Aboriginal people as cough remedies or general tonics.[2] To determine a dose proportional to body size, a branch of the tree was held between the elbow and an outstretched finger.[3] Other units of measure used to determine dosage included the width of the fist, the width of the thumb and the distance from forefinger to pinky in an outstretched hand.

The mathematics of the body

The Aboriginal method of determining medicine doses is the basis of the following exercise exploring allometric relationships among sizes of body parts. This exercise will build understanding of fractions and the use of scatter plots in searching for patterns. It will also lay the basis for understanding correlation and regression in later grades.

Student at Mi'kmawey School in Chapel Island, Nova Scotia, tests the vitamin C content of conifer tea.

Note to teachers: The scatter plots will show a positive linear relationship between forearm length and height. There may be a slight difference between males and females, depending on the number of individuals in the study (i.e., slight differences will show up only in larger sample sizes). Weight differences should introduce significant scatter, meaning that slimmer individuals will obtain a higher dose of vitamin C when measurements are based on forearm length. In fact, dosages of many modern medicines are based on weight for this reason. With modern diets, there is more variability in height/weight ratios than would have existed when Aboriginal people lived off the land. This should be a topic for class discussion.

Procedure:

1. Make a data table with columns for forearm length, total height, weight, age and gender. Have students measure and record data on a group of classmates or a group of people of different ages.
2. Plot the data on a scatter plot, with height on the x axis and forearm length on the y axis. Make observations about the average heights and forearm lengths, the spread of the data and the slope of the relationship between height and forearm length. Is there a relationship between the length of the forearm and height in humans?
3. Ask students to plot their own height and forearm length on the scatter plot and determine the ratio. Where do they fit with respect to their classmates?
4. Does this ratio change with age or gender? Recreate the scatter plot. Group the data into age categories and plot them using a different symbol for each category. Do the types of symbols group together? Repeat, this time grouping the data into two gender categories. Do the types of symbols group together?
5. How much does the ratio vary with weight? Make a scatter plot of data gathered from people who are approximately the same age. Plot the ratio between forearm length and height against weight. What is the trend? Make an assessment about the amount of scatter.
6. Using the forearm technique to measure a dose of tamarack for making tea, would a thin person obtain more or less vitamin C than a heavier person of the same height? Use data from Step #4 above and group data on the basis of weight categories.

Measuring vitamin C in conifer teas

The diets of the early Aboriginal people who obtained food from the land benefited their bodies in many ways. There was no need for vitamin supplements because their food was rich in vitamins. Modern diets, on the other hand, include many foods that have little nutritional value.

Not many students think of food when shown a coniferous tree. In itself, this is an eye-opener that encourages students to look at their environment in a different way. The following exercise has students compare the nutritional value (vitamin C concentration) of traditional and modern foods containing vitamin C. Topics that can be discussed in conjunction with this exercise include: What is vitamin C? Why do our bodies need it? What happens if we do not have enough? How do modern people obtain vitamin C in the winter? How much vitamin C is in tamarack tea, spruce tea or balsam fir tea compared to a modern source, such as orange juice?

Preparing tea

Prepare teas from several local coniferous species. Needles from various species of conifer, such as tamarack (*Larix laricina*), red spruce (*Picea rubens*) and balsam fir (*Abies balsamea*), were made into teas by Aboriginal people in eastern North America. Teachers and students in other regions should seek out local traditional ecological knowledge to determine which of the coniferous trees in their area may be useful for this exercise.

The amount of the tree used should be a length of a healthy branch equivalent to the distance from elbow to the tip of an outstretched third finger. Break up the measured length of branch and put the needles and small branchlets in a pot of water heated to a rolling boil (the volume of plant material and water should be roughly equivalent). Remove the pot from the heat and steep for approximately five minutes. Strain the liquid through folded cheesecloth into a cup, and sweeten to taste with maple syrup.

The amount of vitamin C in each tea can now be compared to the amount contained in standard fruit juices, fruit drinks and commercial herbal teas.

An iodine indicator solution is used to compare the amount of ascorbic acid in various juices and conifer teas.

Comparing vitamin C concentration

This is a simple comparison of concentrations of vitamin C, based on differences in the intensity of colour resulting from the chemical reaction between ascorbic acid (vitamin C) and iodine.[4] Iodine will turn a solution of cornstarch and water a purple-blue colour, but it reacts with ascorbic acid to produce a colourless product called dehydroascorbic acid. In this test, equal volumes of a purple-blue indicator solution made of starch and iodine are added to equal volumes of the test liquids. If the sample has very little vitamin C, the solution will remain a deep purple-blue; if the sample has a higher concentration of vitamin C, it will become lighter as the purple-blue iodine becomes colourless in reaction with the ascorbic acid. The more vitamin C in the test liquid, the lighter the solution. With this method, you can compare relative vitamin C content and rank foods from highest to lowest.

Materials: cornstarch, 2% iodine solution (available from pharmacies), eyedropper, water, hot plate, heat-proof beaker or small pan, 15-ml test tubes (one per sample), samples of a variety of conifer teas and fruit juices

Procedure:

1. Make a starch solution by mixing 1 tablespoon of cornstarch into enough water to make a paste. Add 250 ml of water and boil for 5 minutes.
2. Using the eyedropper, add 10 drops of the starch solution to 75 ml of water to make a more dilute starch solution.
3. Add enough iodine to the starch solution to produce an indicator solution with a dark purple-blue colour (approximately 1 ml).
4. Put 5 ml (1 teaspoon) of indicator solution into each of several 15 ml test tubes or vials, one tube for each liquid to be tested.
5. To each tube or vial, add 10 drops of test liquid (juice or tea), using a clean eyedropper. Between samples, rinse the eyedropper with water.
6. To judge the intensity of colour, hold the test tubes against a white background. Line up the tubes from lightest to darkest purple. Vitamin C causes the purple indicator solution to lose its colour. Therefore, the samples with the highest concentration of ascorbic acid (vitamin C) will be the lightest colour of purple.

Titration method: For higher grades, a more complex experiment can be performed which includes standardizing the titration and calculating amounts of vitamin C. In the titration method, a cornstarch solution is added to equal volumes of the liquids to be tested, and then iodine is added dropwise to each solution. As the iodine reacts with ascorbic acid (vitamin C) in the solution, the colour remains the same. When all the ascorbic acid is neutralized, the iodine reacts with the starch in the solution and the colour changes. The amount of iodine added is directly related to the amount of vitamin C in solution.[5]

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Acknowledgement: The authors thank **Jane Meader** from the Membertou First Nation for her discussion and inspiration, and for suggesting this topic for an activity.

Notes

1. J. Rousseau. *Jacques Cartier et la Grosse Maladie*, Translated by J. L. Launay, Ronald's Printing, 1953.

2. D.E. Moerman, *Native American Ethnobotany*, Timber Press, 1998.

3. Jane Meader, Membertou First Nation, personal communication.

4. The procedure for this experiment was adapted from "Science Projects About Nutrition & Health," Science Made Simple, 2006, online September 9, 2009 at <www.sciencemadesimple.com/nutrition_projects.html>.

5. For instructions, see "Which Orange Juice Has the Most Vitamin C?" in *Science Buddies*, Kenneth Lafferty Hess Family Charitable Foundation, 2002–2009, online September 9, 2009, at <www.sciencebuddies.org/mentoring/project_ideas/Chem_p044.shtml?from=Home>.

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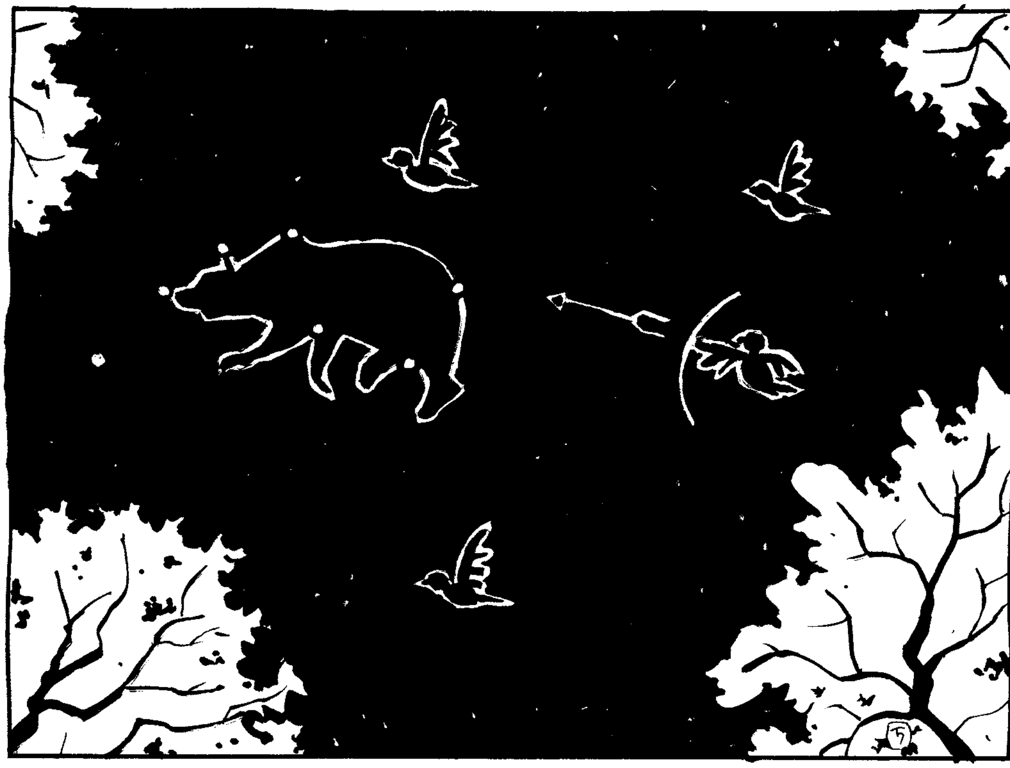

Tom Goldsmith

Traditional Legends: Meanings on many levels

A lesson in astronomy and storytelling for high school students

by **Annamarie Hatcher**, **Sana Kavanagh**, **Cheryl Bartlett** and **Murdena Marshall**

IN ALL CULTURES, traditional legends have meanings on many levels. One such legend is the Mi'kmaq story of the Celestial Bear hunt, which explains changes in the night sky over the course of a full year. In the Indigenous world view, all life follows cycles; and in the Mi'kmaq worldview, that which happens on Earth is mirrored in the sky (see sidebar, "The Legend of the Sky Bear"). The story of the Celestial Bear is a fascinating topic of discussion that can be reinforced by nighttime sky-gazing expeditions. If group sky-gazing is difficult to arrange, teachers can prepare take-home sky-gazing assignments that can be completed under the supervision of parents or guardians.

The constellation commonly known as Ursa Major was recognized as a bear by many ancient peoples, including the Mi'kmaq.[1] In the Mi'kmaq legend, the seven stars "following" the Bear, or *Muin*, were thought to be hunters chasing it across the night sky.[2] This group of seven hunters consists of the three stars that form the handle of the Big Dipper (Robin, or *Jipjawej*; Chickadee, or *Jikjaqoqwej*; Moosebird/Gray Jay or *Nikjaqoqwej*) and four stars in the constellation Bootes (Passenger Pigeon, or *Ples*; Blue Jay, or *Tities*; Owl, or *Kukukwes*; and little Saw-whet Owl, or *Kupkwe'j*). *Muin's* den is what others know as Corona Borealis.

In the spring, *Muin* emerges from the den, and *Jikjaqoqwej* (Chickadee) is visible behind her. The seven hunters chase *Muin* all spring and summer. In the autumn, the hunters in the rear start to lose the trail. First *Kupkwe'j* (Saw-whet) falls back, being too small to keep up. It is said that if you laugh at *Kupkwe'j* for losing the trail, he will descend from the sky and light your clothing with fire from his birch bark torch after you fall asleep.[3] Then *Kukukwes* (Owl) loses the trail because he is too heavy. *Tities* (Blue Jay) and *Ples* (Passenger Pigeon) also lose the trail. Then, as *Nikjaqoqwej* (Moosebird) is about to lose the trail in mid-autumn, *Muin* stands up on her hind legs. This gives *Jipjawej* (Robin) a clear shot, and he kills *Muin* with his bow and arrow. Covered with Bear's blood, *Jipjawej* flies to a maple tree and shakes. The maple tree turns red with *Jipjawej's* blood, and that is why all maples turn red at this time of year and why the *Jipjawej's* (Robin's) breast is red. After *Jipjawej* kills the bear, *Jikjaqoqwej* (Chickadee) arrives with his cooking pot. The two hunters carve off some of the meat and cook it. As they prepare to eat, *Nikjaqoqwej* (Moosebird) shows up for his share. This works so well for him that he continues to show up at the last minute to take food whenever animals

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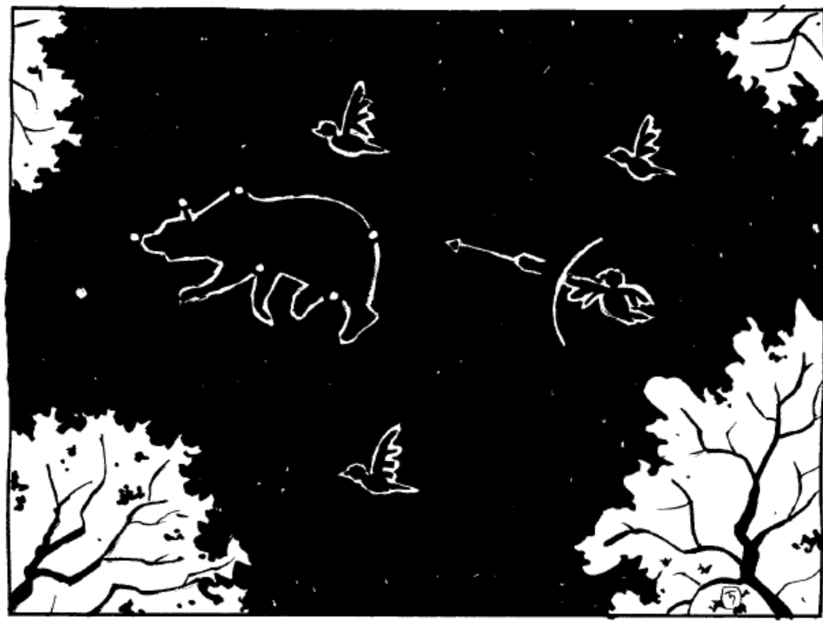

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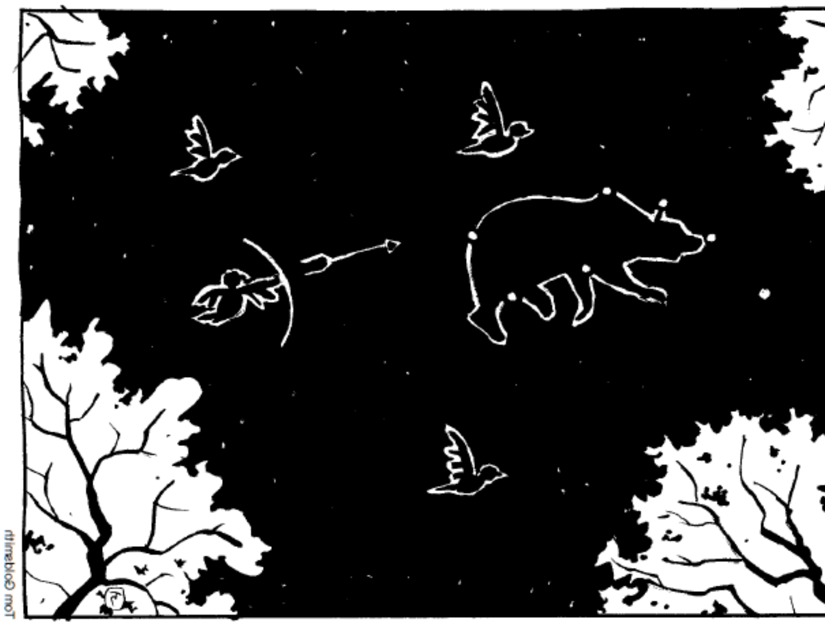


correct

are hunted. Thus his Mi'kmaq name is *Nikjaqoqwej*, meaning "He-who-comes-at-the-last-minute."[4] During the winter, the skeleton of *Muin* lies on her back, and her spirit stays invisible until the spring when a new *Muin* with the same spirit emerges and the hunt begins again. Thus, organic life begins anew but spirit lives on forever.

Astronomical explanation

Every motion that the stars appear to make is actually due to the motion of the Earth. Our planet rotates on its axis and revolves around the sun. When we see the stars move in one direction, it is because we are moving in the opposite direction. Our frame of reference is the ground, the horizon, trees, houses and other landmarks. Since they are all moving along with us, we perceive ourselves as stationary and the distant stars as being in motion. This is why we should say that the stars "appear to move," but not that the stars "move."

We think of a day as a 24-hour period, but, astronomically, a day is the time it takes for a location facing the sun to make a full turn as the Earth rotates on its axis and face the sun again. If the Earth stayed in the same place in space while it rotated on its axis (which it doesn't), this would be a movement of 360 degrees, the number of degrees in a full circle. In that case, the stars would appear to move 360 degrees over the course of a day, so that if we looked at the stars from the same location and at the same time every night, they would be in the same place. However, when we observe the stars from night to night we see that they appear to change position each night. Why does this happen?

The stars appear to change position from night to night because in addition to rotating on its axis, the Earth is also revolving around the sun. For every rotation, the Earth also moves along its path around the sun. As a result, in order for a location on Earth facing the sun to make a full turn and face the sun again, the Earth has to turn almost one degree *more* than 360 degrees. Since every movement of the Earth appears to us as motion in the stars, it appears that the stars move over the course of a day. If we check the stars at the same time each night, we see what appears to be a change in position of nearly one degree every night. The story of *Muin* and the Seven Bird hunters describes this pattern over a whole year.

Many students are unaware that the sky presents an ever-changing view of celestial bodies, and the *Muin* story is an appealing and memorable introduction to these changes. Students can better grasp the celestial influences that govern seasons when they see corresponding seasonal changes in the patterns in the sky. The complex interrelationships between Earth and other celestial bodies that are examined in the *Muin* story also ground astronomy concepts strongly in the student's home place. This is because the observed relationships of sky objects are relevant to particular latitudes, illustrating how Indigenous science is grounded in a subjective connectivity between natural patterns and pattern seers that is not emphasized by Western science. The *Muin* story is relevant at mid-northern latitudes, but would not carry the same message at southern latitudes where there are no circumpolar stars and seasonal Earth cycles do not appear to be reflected in the sky.

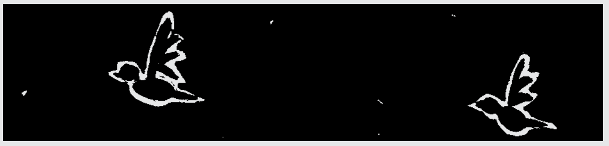
Celestial *Muin*-gazing

In the following activities, students locate *Muin* and the Seven Bird Hunters in the sky and learn that their story describes patterns in the location and movement of stars. In the first activity, students learn the location of key stars described in the story. In the second, they observe the stars at the same time for many nights in order to learn about the motion of the stars from season to season.

The Legend of the Sky Bear

The sky bear comes out of the den
In the spring of each year
To be spotted and chased by seven hunters
The pursuit lasting a time
The chase goes on through the summer
And finally in mid-Autumn
The hunters overtake their prey and kill her
The robin becomes covered with her blood
In the process tries to shake it off
Which he does, with the exception on breast
The gore he trembles
Spattering to the earth below
And there we see Autumn
The red tint on leaves
The reddest on maple
For you see, the trees on Earth
Follow the sight of trees in the sky
The sky maple received the most blood
The sky is the same as the earth
Only older

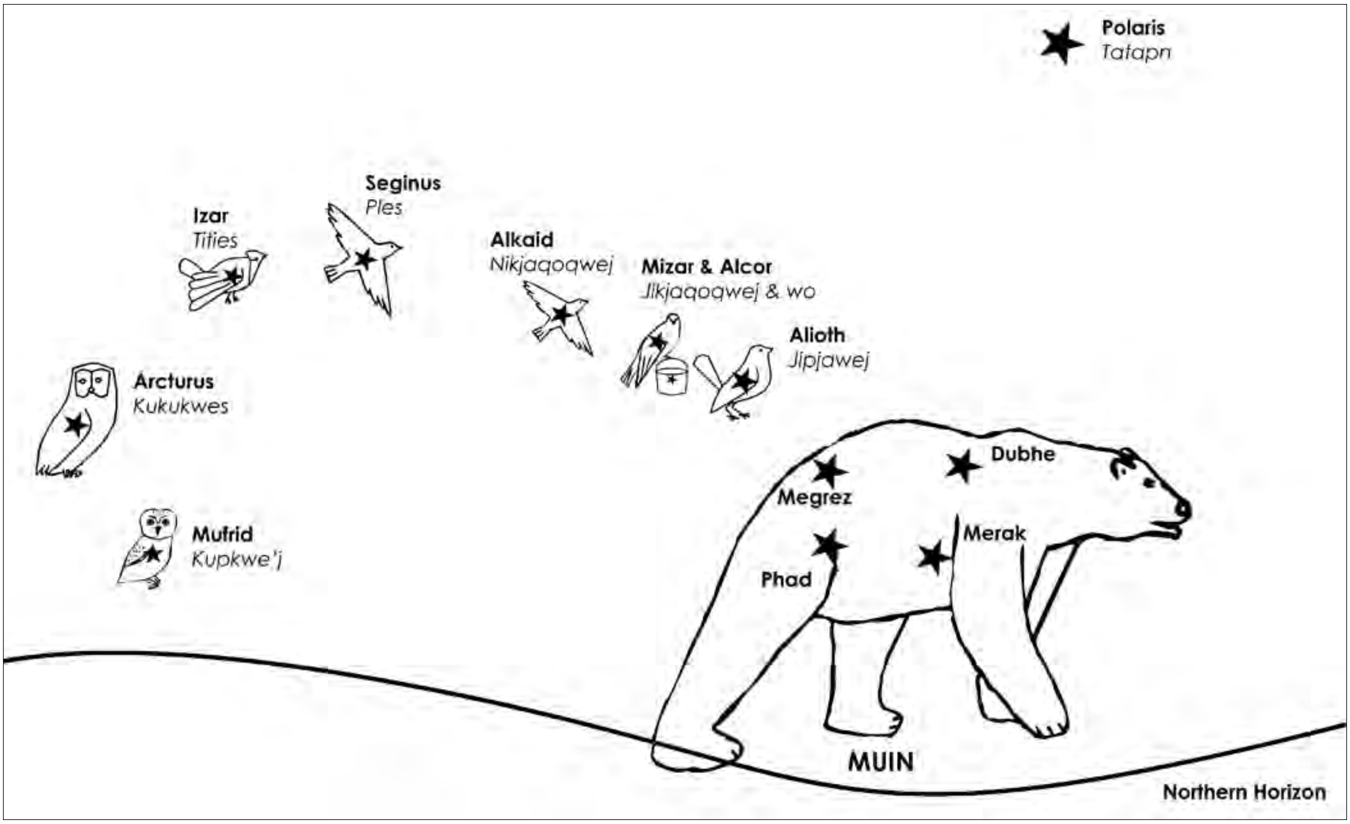
(by Rita Joe, from *Micmac News*, November 1987, p. 42)



We Are The Birds of Fire

We are the stars which sing,
We sing with our light;
We are the birds of fire
We fly over the sky.
Our light is a voice;
We make a road for spirits,
For the spirits to pass over.
Among us are three hunter
Who chase a bear;
There never was a time
When they were not hunting.
We look down on the mountains.
This is the song of the stars.

(from C.G. Leland, *The Algonquin Legends of New England; or, Myths and Folklore of the MicMacs, Passamaquoddy, and Penobscot Tribes*, Houghton-Mifflin, 1884, p. 379.)



Sana Kavanagh

When to stargaze

As we learn from the story, the positions of *Muin* and the Seven Bird Hunters change from season to season. While stargazing can be done at any time of year, these activities focus on the autumn and winter months when early nightfall and long nights make it easier to do stargazing activities with students. This is fitting because the long nights of winter were traditionally a time of storytelling. More stars will be visible on cloudless nights during a new moon, or before the moon has risen, and in a location away from the light pollution of streetlights.

Finding star patterns

A few easy steps can help students orient themselves to find the Mi'kmaq star patterns in the story. To begin, have students locate North with a compass. The star patterns called Bear and the Seven Bird Hunters will be located above the northern horizon. The four stars that are the bear and the three stars that are the first three bird hunters are very bright. Many people know these seven stars as the Big Dipper. Look for these seven stars first.

The seven bird hunters lie along an imaginary line that arcs from *Jipjawej* (Robin), through *Jikjaqoqwej* (Chickadee) and *Nikjaqoqwej* (Moosebird/Gray Jay), until a very bright star is reached. This is *Kukukwes* (Owl). It is also called Arcturus, so stargazers say "Arc to Arturus" to remember how to find the star from the North Star.

Imagine a line running between the stars Dubhe and Merak in *Muin* and extending five times the distance between them. This points us to *Tatapn*, also known as Polaris and the North Star. *Tatapn* is not a particularly bright star. It will always be due north, and its angle above the horizon is equal to the latitude in any given location. *Tatapn* will be directly overhead only if you live at the North Pole. People of many cultures have used this star to navigate at night.

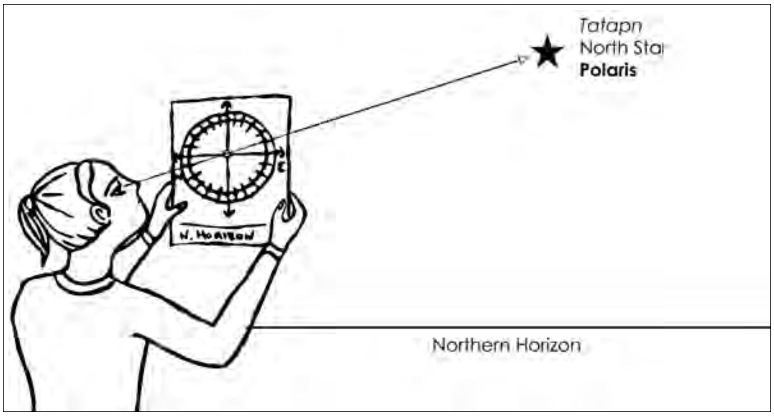
Seasonal Changes

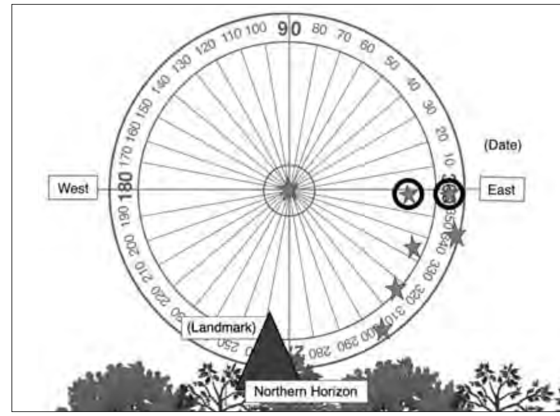
This activity teaches about the seasonal changes of the positions of the stars, which is described in the story of Muin and the Seven Bird Hunters. Students will observe the angle of rotation of the stars at exactly the same time each night.

Materials: copies of the protractor (see page 17), enlarged as much as possible and printed onto transparencies. If possible, print in yellow, which is easiest to see at night.

Procedure:

1. Hold the transparency up so that *Tatapn* (Polaris) appears in the small circle at the center of the figure. Note a stationary physical landmark on the horizon below *Tatapn*. Sketch the landmark onto the transparency with a marker so that observations can always be made from the same location.
2. Keeping *Tatapn* centered in the small circle, move the transparency forward until at least two stars within the Bear or the Bird Hunters appear to be within the largest circle. Mark the position of two stars on the transparency. Mark the date outside the circle.
3. Repeat the observation at regular intervals from the same location and at the same time of night. Ensure that students select a time for observation that will always be dark. Remember that any time of night that is dark on September 21 will be dark until April 21. This leaves





Sana Kavanagh

plenty of weeks for observation, as this date range bridges the longest nights of the year.

A practical interval for observations is once weekly. Daily changes will be difficult to notice because the stars' positions move by less than one degree a day. Weekly observations will result in a larger angle of rotation being recorded. Each time, ensure that *Tatapn* is centered in the illustration and that the physical landmark lines up with the sketch.

The weekly rotation can be measured in two ways. Students can estimate the angle of rotation directly from the transparency tool. For a more precise measurement, draw lines through each star location and lay a protractor over the transparency. (Remember that this protractor must also be centered on *Tatapn*.) The angle of rotation is the difference in angle between two observations of the same star. Divide the angle of rotation by the number of days between observations to calculate the daily angle of rotation.

After eight to twelve observations, ask students to describe the pattern of the star movements, based on their observations.

Extensions: Partner with schools across North America to explore the effect of location on the story of Muin and the Seven Bird Hunters. Select a school at a similar latitude but different longitude to explore how longitude affects the appearance of the night sky. Select a school at a similar longitude but different latitude to explore the effect of latitude on the story in the sky. Students can also research traditional star stories from around the world and learn to connect the patterns in the stars with the stories told in those areas.

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Acknowledgments: We thank **Lillian Marshall**, elder of the Mi'kmaq Nation of Potlotek (Chapel Island), Nova Scotia, a keen observer of the stars who patiently worked with us on the story of the Celestial Bear. We also thank **Jane Meader**, Mi'kmaq Nation, Membertou, for many fruitful discussions of legends.

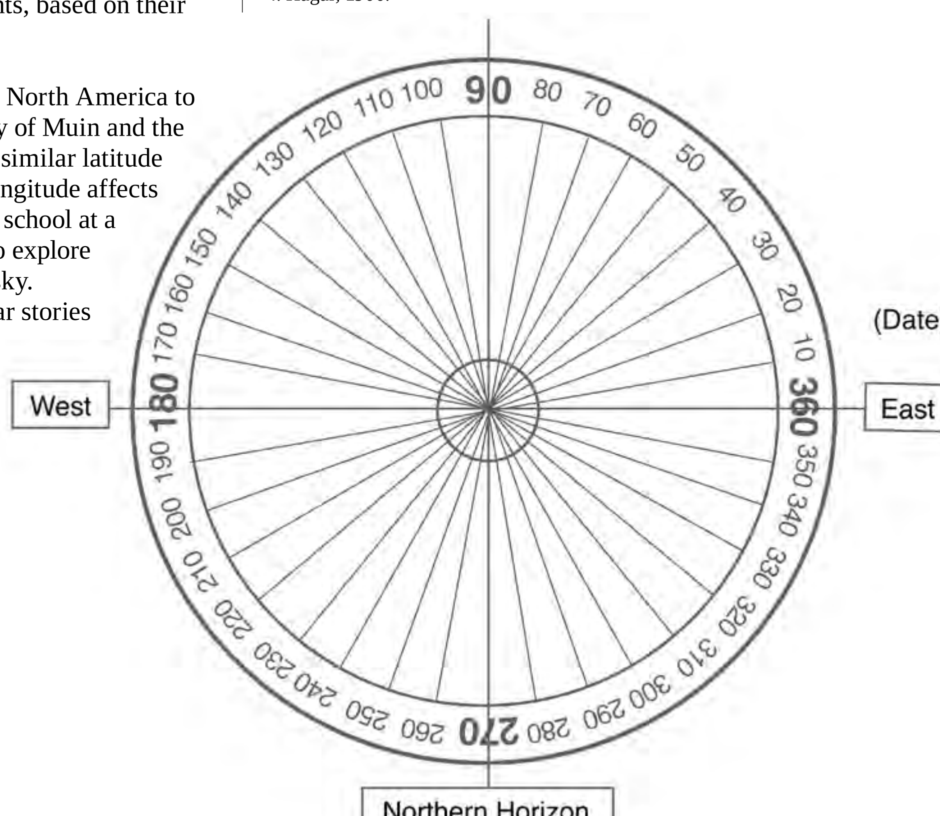
Notes

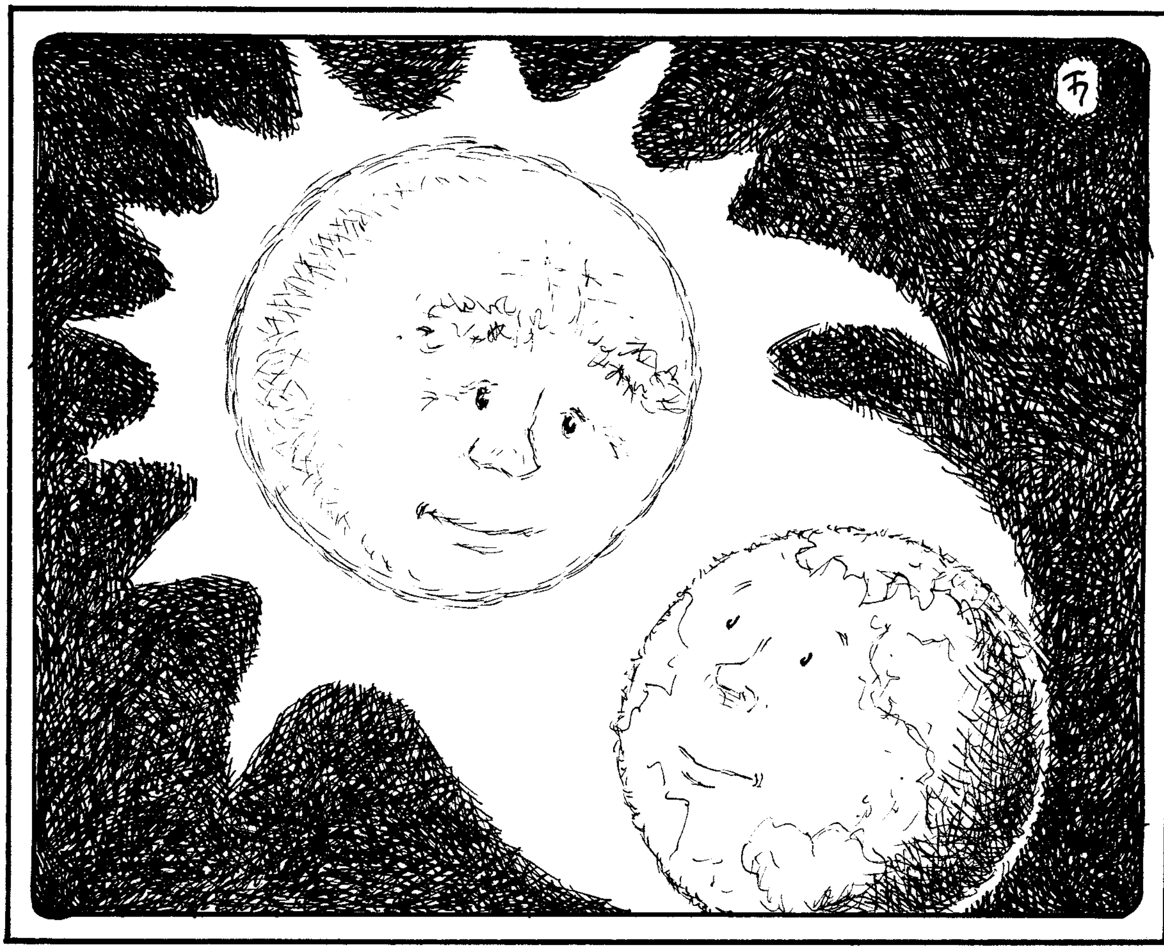
1. Kate Dudding, "The Celestial Bear," 2003, online September 2, 2009, <www.katedudding.com/celestial_bear.shtml>.

2. The story was published by Stansbury Hagar in 1900 from information he had collected from many Mi'kmaq people. An earlier description of the bear story was recounted by Chrétien Le Clercq in 1677, as documented in R.H. Whitehead, *The Old Man Told Us: Excerpts from MicMac History 1500-1950*, Nimbus, 1991.

3. Stansbury Hagar, "The Celestial Bear," *The Journal of American Folklore* 13(49), 1900, pp. 92–103.

4. Hagar, 1900.





Illustrations: Tom Goldsmith

Mother Earth, Grandfather Sun

A "two-eyed seeing" activity that integrates Western and Aboriginal world views in teaching about solstices and equinoxes

by **Cheryl M. Bartlett**

WESTERN SCIENCES tend to emphasize matter and energy and to encourage us to develop object-oriented minds, whereas consciousness is at the heart of the Indigenous sciences. Learning to ascribe consciousness to natural objects can change students' attitudes toward nature by fostering respect and reverence. This in turn may help to bring about the transformations in values and actions that are needed for more sustainable living.

"Two-Eyed Seeing" asks teachers and learners to acknowledge both Western and Aboriginal ways of knowing about nature. This exercise about solstices and equinoxes has students ascribing consciousness to an object which in the Western scientific view is inanimate — the sun. It is useful both in teaching the science concepts related to the seasons and in introducing students to Indigenous ways of "coming to know." While physical models for teaching this topic are plentiful, this exercise encourages learners to shift their consciousness to animate the sun — to "become" Grandfather Sun — and thereby enable him to see the Earth (Mother Earth). The exercise also provides an experiential foundation for discussion of the utility of models in the learning and doing of science, regardless of cultural perspective.

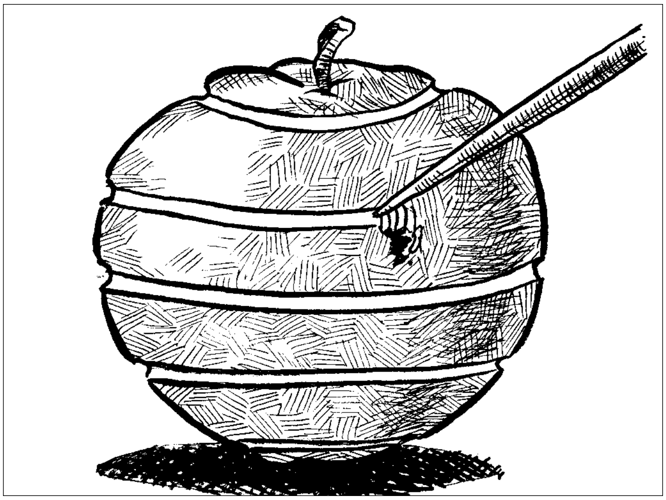
Introduction

In North America, Grandfather Sun and Mother Earth are common English-language renditions of Aboriginal peoples' names for the sun and Earth, respectively. In most Indigenous world views, both are animate. The exercise draws upon the visual sensibility of Grandfather Sun.

Time: 30 minutes

Grade levels: Grades 6–8

Materials: For each student, one apple (preferably round with a dark red peel such that scratching the peel will easily and readily produce distinctly visible white lines); one strong, thin skewer stick (at least 10 cm long); one thumbtack



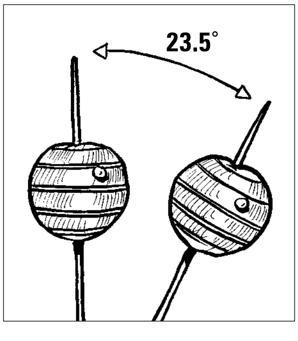
Marking latitudes on "Mother Earth."

Winter solstice in the northern hemisphere.

Procedure:

Mother Earth (the apple)

1. Provide each student with an apple, a skewer stick and a tack. Students will use the apple and stick to create a model of Mother Earth that has the geographical grid assigned to Earth in Western science.
2. Explain to students that the apple's stem and flower remnant (i.e., two oppositional points) mark the Arctic (or North) and Antarctic (or South) poles, respectively. Instruct them to create a latitudinal grid on the apple by deeply scratching the apple skin with the skewer stick as follows:
   - Mark the equator by scratching a line around the middle of the apple.
   - Mark the Tropic of Cancer by making a line around the apple about one-quarter of the distance from the equator to the North Pole (stem). Mark the Tropic of Capricorn by similarly moving about one-quarter of the distance from the equator to the South Pole. These two lines represent the tropics at 23.5° latitude north and 23.5° latitude south, respectively.
   - Mark the Arctic Circle by making a line about one-quarter of the distance from the North Pole (stem) to the equator. Mark the Antarctic Circle about one-quarter of the distance from the South Pole to the equator. These two lines represent the circles at 66.5° latitude north and 66.5° latitude south, respectively.
3. Push the skewer through the apple, from stem to flower, i.e. pole to pole, to represent the Earth's axis.
4. Ask students to determine the approximate latitude of their home location, and place the thumbtack in the apple at the spot approximating home.
5. Have students tip their apples 23.5° to represent Earth's tilt on its axis.

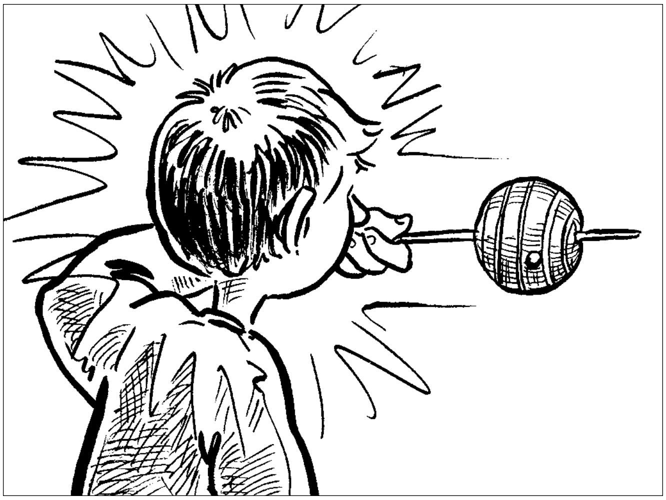


Grandfather Sun (the student)

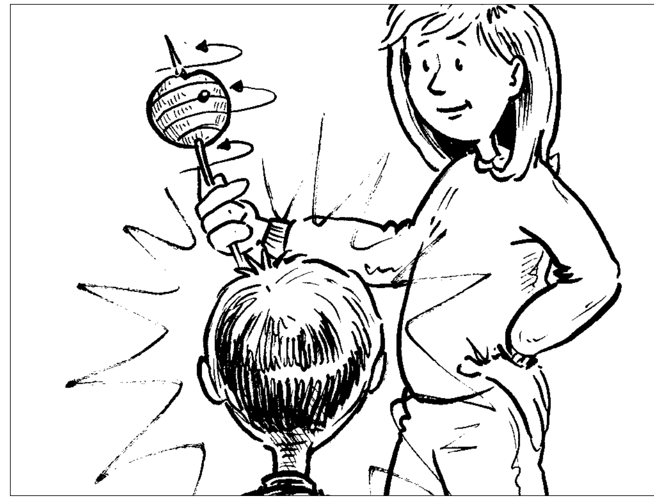
6. Next, Grandfather Sun is added to the model by designating the students' heads as the sun. The model now contains both the Earth and the sun, and can be used to demonstrate the seasons, with a particular focus on the solstices and equinoxes. Ask students to hold Mother Earth at arm's length at the level of their eyes, therefore enabling Grandfather Sun "to see" Mother Earth, i.e., mimic the sun's rays that fall upon Earth.

Solstices

7. Instruct the students to "become" Grandfather Sun and to tilt Mother Earth away from their heads (i.e., with the North Pole pointed away from Grandfather Sun) so that they can see up to, but only to, the near side of the Arctic Circle. In this position, Grandfather Sun should be able to see the South Pole of Mother Earth all the way across to the far side of the Antarctic Circle. (This may require a slight upward adjustment in the level at which the apple is held.)
8. Have students rotate the apple to mimic Mother Earth's rotation on her axis. As this happens, each student should come to realize that he or she (as Grandfather Sun) never sees higher on the apple than the line marking the Arctic Circle. This particular day is the winter solstice. At this time of the year, 24 hours of darkness would be experienced above the Arctic Circle (since Grandfather Sun never sees above that line), and concurrently there would be 24 hours of sunlight below the Antarctic Circle.
9. Have students reverse the position of the model so that Mother Earth remains on a tilt but the North Pole is pointed towards Grandfather Sun, i.e., the top of the apple is toward their heads. Instruct the students to, as Grandfather Sun, see the top of Mother Earth all the way across to the far side of the Arctic Circle (this may require slight adjustment in the tilt of the apple and/or slight adjustment in the level at which the apple is held). This position of the apple should enable Grandfather Sun to see the bottom of Mother Earth to the near side of the Antarctic Circle.



Spring and fall equinoxes.



Earth's orbit around the sun.

10. Again, have students rotate the apple to mimic Mother Earth's rotation on her axis. As this happens, students should come to realize that throughout the rotation they (as Grandfather Sun) can see across the whole of the top of the apple to the far side of the line marking the Arctic Circle. This particular day is the summer solstice. At this time of the year, 24 hours of sunlight would be experienced above the Arctic Circle (since Grandfather Sun always sees above that line) and 24 hours of darkness would be experienced below the Antarctic Circle.

Equinoxes

11. Shift the model 90 degrees, so that the North Pole (apple stem) points towards the left or right. As Grandfather Sun, the students should see the top of Mother Earth (i.e., the top of the apple) all the way to the North Pole but no further (this may require slight adjustment in the tilt of the apple and/or slight adjustment in the level at which the apple is held). This position should also enable Grandfather Sun to see the bottom of Mother Earth to, and only to, the South Pole.
12. Again, have students rotate their apples to mimic Mother Earth's rotation on her axis. As this happens, students should realize that throughout the rotation they (as Grandfather Sun) see as much of the top of the apple as they see of the bottom of the apple. These two particular days are spring and fall equinoxes. At these two times of the year, the sun is directly above the equator, and equal hours of sunlight and darkness are experienced.

In the demonstrations thus far, students have "become" the sun and created the sun–Earth relationship in front of their eyes. The strength of this heliocentric "in front of your face" depiction is that it readily enables students to understand that Grandfather Sun sees Mother Earth very differently on the winter versus summer solstices, and on solstices versus equinoxes, and that Grandfather Sun sees Mother Earth similarly on both spring and fall equinoxes. Explanations using the language of Western science can then be given. The weakness in this depiction is that it does not include Earth's orbit around the sun. This is addressed by adding the component described next.

An "around your head" orbit

Once students have come to understand solstices and equinoxes, it is relatively simple to move them toward the more complex understanding of Earth's annual orbit around the sun. Students simply move the rotating apple 360° around their head while maintaining the required tilt (23.5°) of the Earth on its axis. This is easiest if the equinoxes are aligned with the ears. For example, if a student starts with the summer solstice directly in front of her, then movement along Earth's orbit takes the apple to the left ear for the fall equinox, behind the head for the winter solstice, to the right ear for the spring equinox, and back in front of the face to complete one full year. The difficulty in doing this resides with the student trying to retain Mother Earth (the apple) on her consistent, required tilt while also rotating her and also orbiting around Grandfather Sun (the student's own head). This gymnastic challenge is easily overcome by having two students work together, one being Grandfather Sun (but standing still) and one moving in a circle around the sun while rotating the apple on its axis. An additional request could be to have the student who is Grandfather Sun rotate to "see" Mother Earth (the apple) through all four seasons.

Questions for discussion

1. Sun rays

- What is the relationship between the sun's rays (or sunshine) and Grandfather Sun's "seeing" in this model? *(Grandfather's "seeing" represents the sun's rays.)*
- How are the sun's rays described in Western science? *(As waves of electromagnetic energy.)*
- In the summer, do the sun's rays feel warm or cold on your skin? *(Warm.)*
- Do you think Mother Earth can "feel" the sun's rays as you can? In what ways is the answer yes, and in what ways no? *("No" in that although sun rays do warm surfaces, Western science does not ascribe the sensory ability "to feel" to the Earth. "Yes," indirectly, in that life on Earth ultimately depends on sun rays and some life forms are capable of feeling.)*

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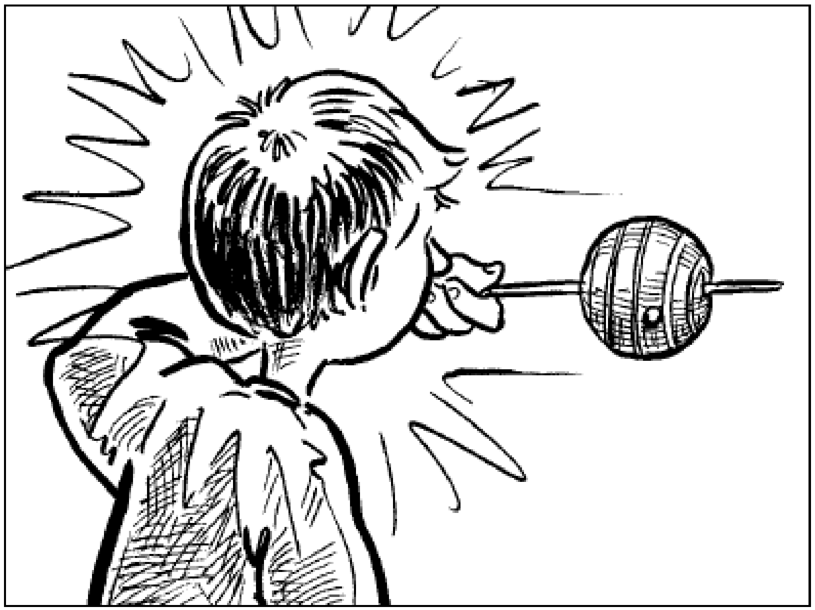
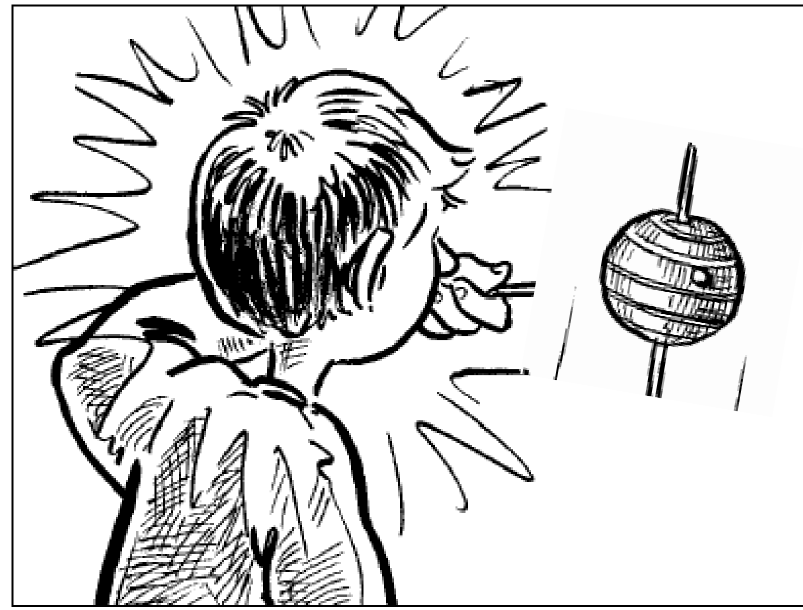


Spring and fall equinoxes.

wrong



Spring and fall equinoxes.

correct

2. Daylight and darkness

- When Grandfather Sun sees Mother Earth's surface, does that part of Mother Earth experience this as light or darkness? *(Light, i.e., day time. Regions that are out of sight of Grandfather Sun experience darkness.)*
- In the United States and Canada, what day of the year has the shortest period of daylight? Is this a solstice or an equinox? Which one? *(winter solstice.)*

3. Hemispheres

- What part of the apple corresponds to the northern hemisphere of Mother Earth? *(The entire region north of the equator.)* What part corresponds to the southern hemisphere? *(The region south of the equator.)*
- In what hemisphere are United States, Canada, Australia? China? Argentina? Mexico?

4. Solstice

- When does Grandfather Sun see the greatest area of Mother Earth's northern hemisphere? *(At the summer solstice.)*
- In United States and Canada, what day of the year has the longest period of daylight? *(The summer solstice.)*

5. Equinox

- When does Grandfather Sun see an equal amount of area in both the northern and southern hemispheres? *(At the spring and fall equinoxes.)*
- At this time of the year, what is the relationship between the periods of light and dark in one whole day? *(They are equal.)*
- What does the "equi" in "equinox" mean? *(Equal.)*

6. Model manipulation

- How much would the Earth have to tilt on its axis in order for Grandfather Sun to be able to see all of the northern hemisphere all the time? *(This would require a 90° tilt with the North Pole pointed at the sun.)*
- What changes in the periods of light and dark in a day would this produce in the area where you live? *(In the northern hemisphere, daylight would occur all day, all year.)*
- Is there any planet in our solar system where this type of tilt does occur? *(Uranus has a tilt of 98°.)*

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